NATURAL STONE FROM SARDINIA

CONSORZIO VENTUNO

POLARIS

P.O.P. SARDEGNA
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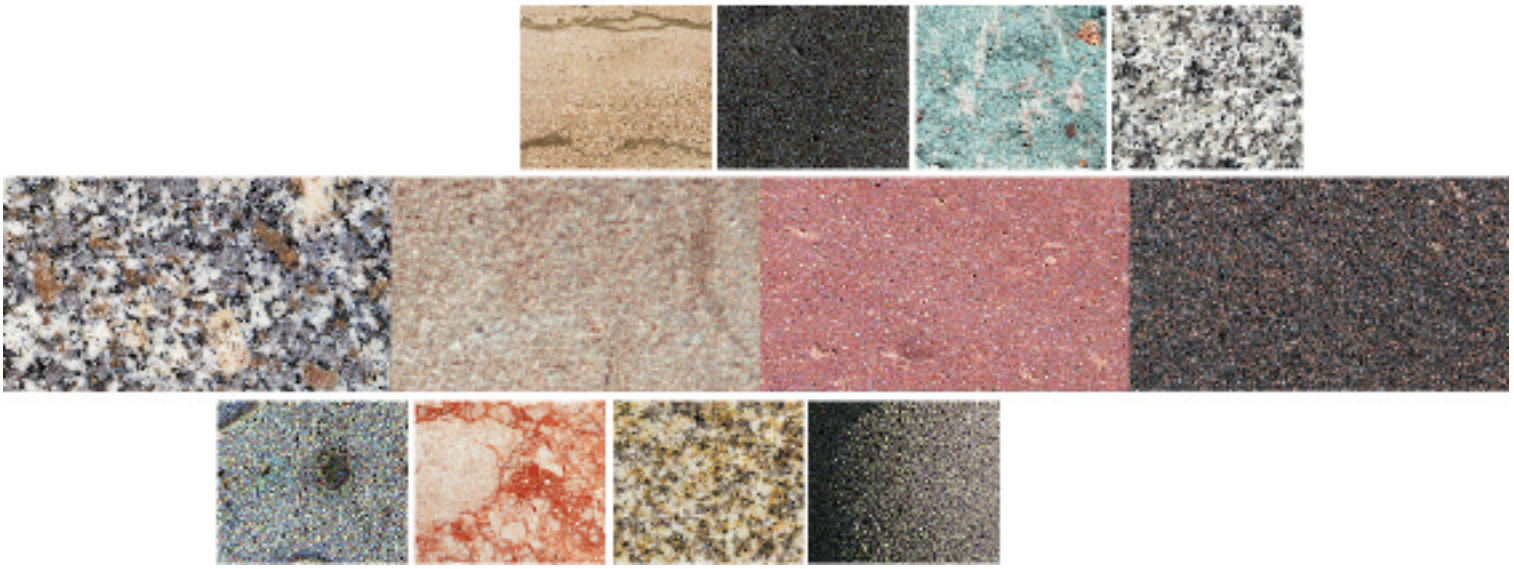

Pilot Project
‘Natural Stone from Sardinia’

The natural stone sector in Sardinia has developed thanks to the work of a host of small and medium-sized firms which quarry and fabricate dimension stone following an ancient tradition of stone use. The stone industry of Sardinia, which revolves mainly around two major production districts: Gallura for granite and Orosei for marble, currently comprises 230 operating quarries overall. The largest quarries are also equipped with fabrication plants for processing primary blocks into semi-finished and finished products.

Stone fabricators include both large operations using advanced industrial methods and smaller craft sector enterprises. The flexible organization of the dimension stone chain on the island makes it possible to obtain both a complete range of standardized products and custom orders designed to meet special functional and aesthetic requirements.

Consorzio Ventuno — the Regional agency for assistance to SMEs — supports the Regional production system by means of actions aimed at reinforcing national and international competitiveness. To accomplish its tasks, Consorzio 21 provides direct services to individual enterprises and launches innovative programs and pilot projects targeted by business sector, according to its strategy of promoting the development of territorial industrial districts and production systems.

This guide was created as part of the pilot project ‘Dimension Stone: Collection and Publishing of Information Resources for the Stone Sector’, in which nine companies and the two main consortia of the Regional stone sector have taken part. The project aims at developing technical and promotional resources on Sardinian dimension stone products, so as to disseminate knowledge of their quality, properties and applications among potential buyers.

This guide provides an overview of the Regional stone industry, covering both quarrying and fabrication. It deals not only with granite and dimension limestone (marketed under the commercial name of Orosei ‘Marbles’) but also the other types of valuable dimension stone that have recently come to the fore, such as basalt and pyroclastic rocks (‘Trachyte’).

This guide provides detailed descriptions, accompanied by a great number of photos, of standard stone products and their main applications, both traditional and innovative. It also contains information on installation systems and associated specifications.

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The geological and petrographic characteristics of each stone are described, as well as its physical and mechanical properties, and its quarrying and processing methods.

In the framework of the overall information project, this guide is complemented by a software program and an Internet site.

The plug-in software is an application which shows jpeg format files, provides the operator with details on material installation and contains a link to the Internet site designed for the project. This application can be integrated with various types of solid modeling software.

The web site: http//www/lapideisardi.it has been designed in a user friendly manner, to enable easy browsing and search. It has a free and a reserved area. The free area contains the texts and images (photos, drawings, installation sketches etc.) created within the framework of the pilot project. The reserved area allows users to download the guide and exchange commercial information with the firms involved in the pilot project.

Antonello Fonnesu
President of Consorzio Ventuno

Guide
‘Natural Stone from Sardinia’

This guide, the site www.lapideisardi.it and the other multimedia tools of the Project ‘Natural Stone from Sardinia’ make up a data bank system — organized into different search criteria and browsing levels according to the resource consulted — on the technical characteristics and production techniques of the main types of dimension stone produced in Sardinia.
This guide illustrates in detail standard Granite, Marble, Basalt and Pyroclastic Stone products and their applications, and is accompanied by a comprehensive set of original photographs. It does not attempt to cover the whole Regional stone sector but rather aims at providing an easy-to-consult introduction to the broad offer available.
A vast amount of technical information and photographs was collected in the making of this guide; in due course, all this material will be published in the site www.lapideisardi.it

(Editor’s note)

Natural Stone from Sardinia

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One of the photos that have characterized the information campaigns sponsored by E.M.S.A. (Sardinian Mines Agency) to promote the natural stone industry of Sardinia.

By kind permission of: E.M.S.A.

Use of dimension stone in the world

(year 2000).	
Millions of sq m installed	650*
Flooring	36.5%
Paving	9.5%
Stairs	3.5%
Interior veneer	10%
Special works	12.5%
Structural works	10%
Funerary and sacred art	15%
Other uses	3%

**(+9.4% on 1999;+49.3% on 1994).*

Countries which in the year 2000 sold more than 1 million tons of dimension stone.

In order: China, Italy, India, Spain, Portugal, Brazil (in 2000, China replaced Italy at the top of the list for the first time). These 6 countries account for 63% of world exports.

Countries which in 2000 imported over 1 million tons of natural stone, in order: Italy, Germany, the United States, China, Japan, Taiwan, France.

Dimension stone use by country and population

(year 2000) - world average=10.8 m 2 /100 inhabitants.

Country	millions of m^2	m^2/100 inhabitants
China	63,600	5.2
Italy	59,300	103
United States	46,600	17.4
Spain	43,070	109
Germany	40,200	49
Japan	33,400	26.5
India	28,200	2.9
France	36,350	45
South Korea	22,000	48
Taiwan	18,800	87.3
Greece	15,700	150
Saudi Arabia	15,200	79.8
Brazil	11,500	7.2
Belgium	11,000	108
Turkey	10,650	16.8
Switzerland	10,050	141.5
Portugal	9,140	91
The Netherlands	7,090	46
Mexico	6,000	6.5
Austria	6,600	81.7
South Africa	4,490	10.5
Finland	3,090	59
Argentina	3,450	9.7
Canada	2,260	70
Norway	2,700	63.2

Source:

Based on data by the European Statistical Office - www.techstone.it - ACIMM - Stone 2001.

Note on the Dimension Stone Industry in Sardinia

For many decades now, the dimension stone sector (quarrying and working) has been one of the most important industries in Sardinia. The major commercial stone types on the island — in terms of quantities produced and of spin off — and those with practically inexhaustible supply, are in order: granite, marble, basalt and pyroclastic rock (partly marketed under the commercial name of trachyte). Granite and marble are mostly quarried in well-defined areas of Central and North-Eastern Sardinia, while basalt and pyroclastic rock quarries are mostly located over a large area in Central-Western Sardinia.
Other types of ornamental stone extracted and worked on the island (but which are not included in this Guide) are phyllite and sandstone, followed by a number of other stones: travertine, white and black limestone, porphyry (gray, green or yellow), yellow and red onyx, slate, tuff, jasper, obsidian and alabaster. The deposits of some of these stones have been almost exhausted, and this means that they can be used for relatively small scale works or for artistic handicraft production.
The production chain of the Sardinian stone sector comprises quarrying companies (about 230), stone fabricators, and companies that both quarry and fabricate. In the past, the Sardinian stone industry mostly focused on quarrying activity, but over the last several decades, modern fabrication and finishing plants have been set up and have expanded steadily. Today, the dimension stone companies of Sardinia process primary blocks, using state of the art technology to cut blocks and slabs and to manufacture finished products which are marketed — and appreciated — globally.

Historical and commercial names of natural stones often differ from their petrographic classification. In this Guide, stones are called by their trade name: e.g. Granite instead of the petrographic term granitoids; Marble instead of compact limestones; Basalt instead of basalts; Trachyte instead of pyroclastic stone. The petrographic characteristics of each stone are listed in the technical sheets in the respective chapters.

Stone products

UNI regulation No. 8458 classifies stone products used in the building and ornamental stone industries in four commercial categories: granite, marble, travertine and stone. The latter category covers a variety of rock types, which can be further divided into two main groups:

Soft and/or scarcely compact stones

Sedimentary rocks and pyroclastic rock (tuffs, peperinos, some trachytes).

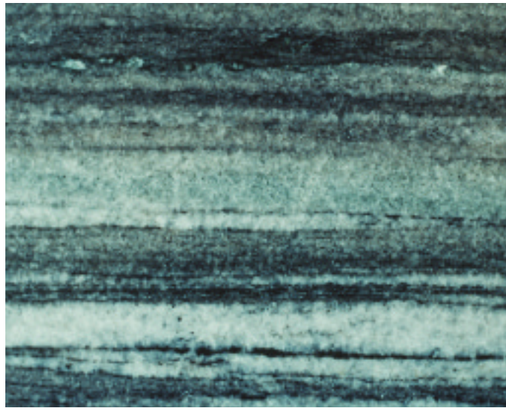
Hard and/or compact stones

Natural cleavage stones.

Volcanic rocks (basalts, some ignimbrites, some trachytes etc).

Lesser stone types of Sardinia

A polishable limestone quarried and fabricated in Central-Eastern Sardinia. It is sold under the name of “Pedra ‘e Ferru” (Iron Stone).



Geologic Map of Sardinia

Mapping: Quarry Office of the Region of Sardinia and Progemisa S.p.A.

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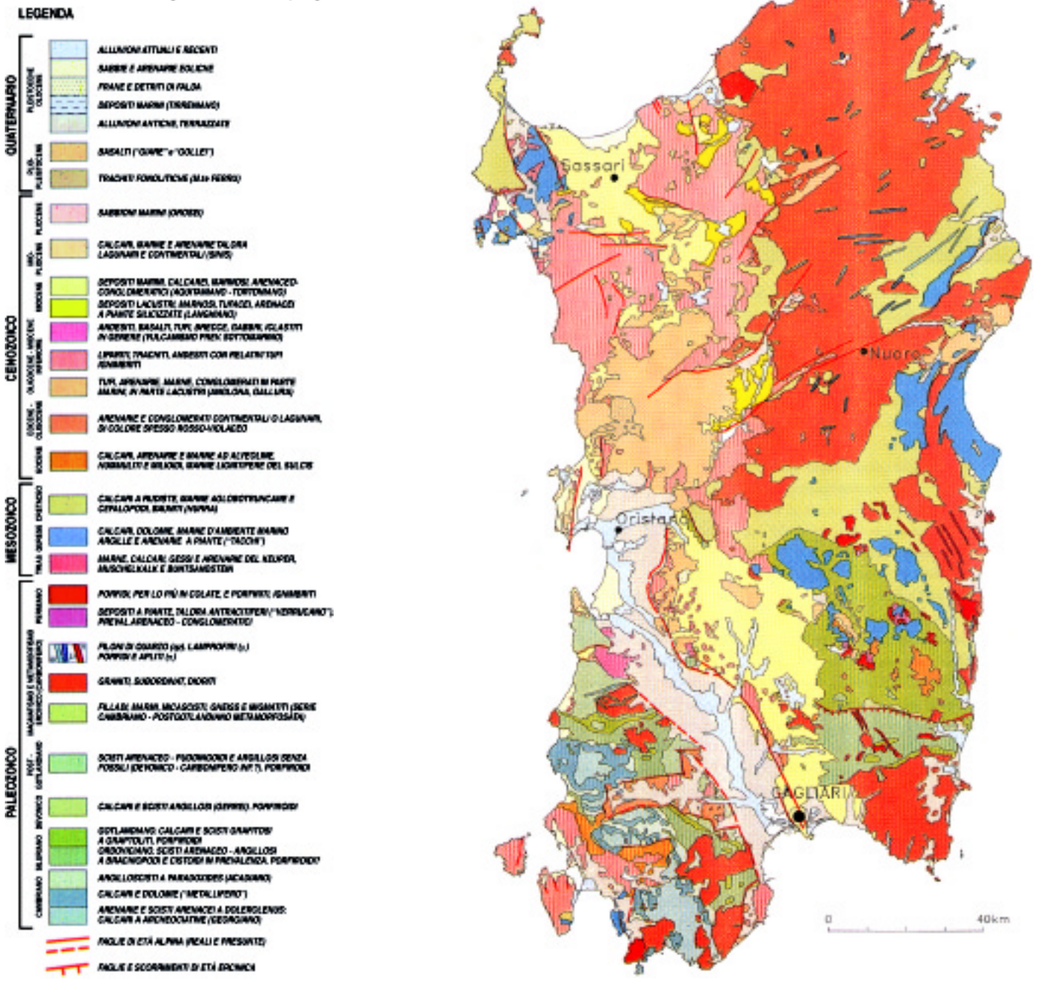


Note on the geology of Sardinia

Sardinia has an extremely ancient geological history, which can be traced by analysis of the rock outcrops and comparison with other areas of the Central-Western Mediterranean. It is geologically quite distinct from the remainder of the territory of Italy. Almost all geological eras are represented across its 24,000 sq km territory, making up a natural collection of varied and valuable rock types.

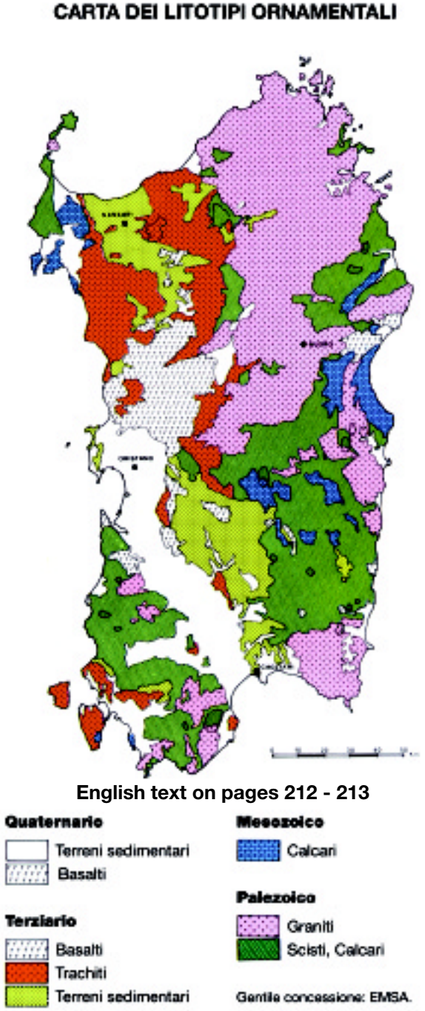
The island's rocks we can identify with certainty as being the most ancient date back to the Lower Cambrian Period. They mark the start of an almost unbroken sequence that ends between the Carboniferous and the Permian. This Paleozoic sequence (now metamorphosed but originally made up of sedimentary and volcanic rocks) was involved in the Hercynian orogeny, which, more than 300 million years ago, gave rise to the granitoids which today form outcrops over large areas of the island.

The ancient base of Sardinia thus consists of granites and metamorphic rocks deriving from Paleozoic sediments and volcanic rocks.

In the following eras, for most of the Mesozoic and the Early Cenozoic Eras, the base was almost completely submerged (apart from brief periods of emergence) and covered by huge quantities of calcareous deposits. These sediments formed the upland plateaux and "tacchi" visible today over much of the island; those dating back to the Jurassic Period form the deposits nowadays quarried for dimension stone production.

The Middle Cenozoic was marked by new, mainly extensional tectonic phenomena, which generated the Sardinian rift. The associated volcanic phase, which was quite lengthy and covered large areas, produced all the pyroclastic rocks and some of the lavas nowadays commercially exploited.

The end of the Cenozoic marked the end of crust movements. However, after a quiet period a new extensional phase began: it was to last from the end of the Tertiary to the Early Quaternary, affecting especially Central-Southern Sardinia).



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Outcrops
A view of the Central-Eastern coast of Sardinia.

An Age-old Island
The most ancient tocks in Italy are thought to be the metamorphic outcrops of South-Western Sardinia, dating back to the Cambrian and perhaps pre-Cambrian periods.

Hercynian Orogeny
Orogenic cycles give rise to mountain ranges along the boundaries between continental plates.
The Hercynian orogeny, spurred by the collision of the European and African plates, started 340 million years ago and lasted about 130 million years. Roughly speaking, Central-Southern Sardinia belonged to the African plate, while Central Northern Sardinia belonged to the European plate.

During this cycle, basaltic lava flows originated several large plateaux (Central-Northern Sardinia) and 'Giare' or tablelands (Central-Southern Sardinia).

Geological Eras (duration in millions of years)
and Periods

Archeozoic (4,200-600)
Ended with the Caledonian orogeny.
Precambrian

Paleozoic or Primary (600-250)
Ended with the Hercynian orogeny.
Cambrian, Ordovician, Silurian, Devonian, Carboniferous, Permian

Mesozoic or Secondary (250-60)
Ended with the disappearance of the dinosaurs.
Triassic, Jurassic, Cretaceous

Cenozoic or Tertiary (60-1.5)
Paleocene, Neocene

Neozoic or Quaternary (1.5-0.01)
Pleistocene, Holocene.

Rock Classification

Rocks are divided into three great classes, based on their genesis: igneous (also magmatic or eruptive), sedimentary and metamorphic.
Igneous rocks: these derive from the cooling and solidification of molten masses at extremely high temperatures, coming from the depths of the earth (magma). they appear as outcrops on only 10% of the earth's surface but account for about 95% of the volume of the lithosphere. Igneous rocks are further divided into **intrusive** (granites, diorites, syenites, gabbros etc.) and **extrusive** (basalt, pyroclasts of varying composition). Intrusive rocks arise from magma which does not reach the surface and solidifies slowly under the earth's surface. Their texture is always holocrystalline, i.e. consisting of more or less developed crystals, each distinguishable at sight. Extrusive rocks come instead from lava of variable composition that reaches the surface of the earth, where it solidifies at atmospheric pressure and temperature. This allows the volatile components to escape from the lava. Their structure is characterized by the presence of large, well defined crystals (phenocrysts) set in a matrix of much finer grained crystals and/or glass. When cooling takes place very rapidly, no crystals will form, and the resulting rock will have a glassy appearance: this is the case with obsidian, which in remote times drew traders from all the known world to Sardinia.

Sedimentary rocks: they derive from the deposition of materials broken down by erosion of the earth's crust. According to their origin, they are further classified into **clastic or detrital** (sandstone, breccia etc.), **chemical** (nodular, oolitic and brecciated limestones, travertine, alabaster) and **organic** (limestone, ammonitic marble, dolomite, etc.). Clastic sedimentary rocks are derived from the weathering and deposition of pre-existing rocks. Chemical rocks are formed by chemical processes (evaporation, inorganic precipitation, etc.). Organic rocks arise from the precipitation, mainly in marine depositional basins, of calcium carbonate of animal origin (shells, brachiopods) but may also be formed by the biological activity of other calcite-fixing creatures, (coral reefs, algae, worms etc.).

Metamorphic rocks: (gneiss, marble, slate, phyllites) originate from the transformation of rocks of all types by the action of heat and pressure (**regional metamorphism**) or of large bodies of molten rock (**contact metamorphism**).

Igneous rocks
The different minerals contained in the magma crystallize in a given order, depending on: magma composition, system pressure and temperature, and mineral solidification temperature.
Thus different rocks can be formed from the same magma, depending on whether cooling takes place beneath the lithosphere or on its surface.

Coast of Central-Eastern Sardinia
Extrusive black rock formations

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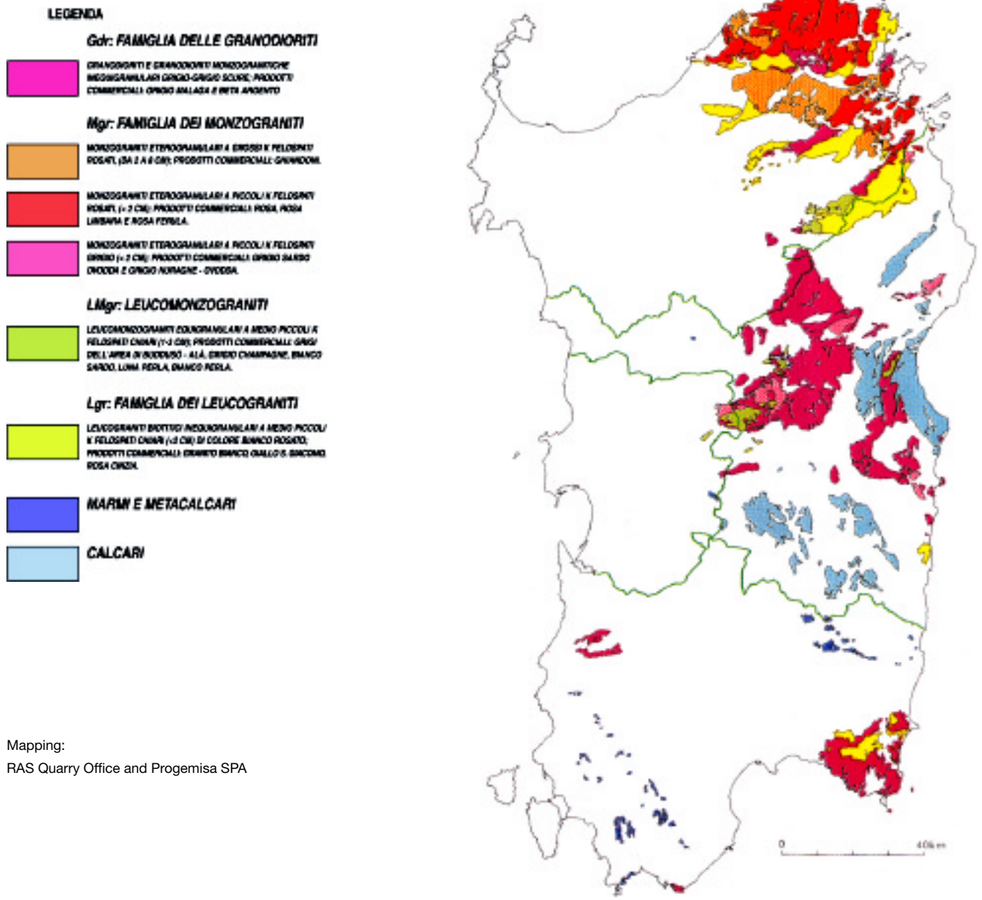
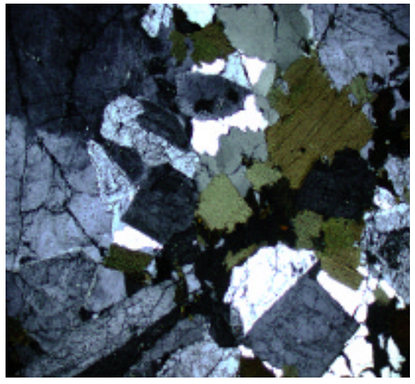
Map showing the areas with exploitable natural stone deposits (Granites, Limestones and Marbles)

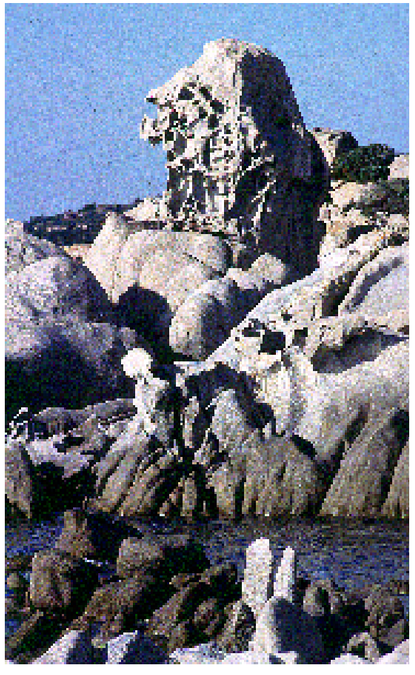


Mapping:
RAS Quarry Office and Progemisa SPA

SARDINIAN GRANITE

Chapter 1 - Sardinian Granite





Geology and Stone Identification

The commercial term 'Granite' groups a number of different rocks whose scientific names are tonalite, granodiorite, monzogranite, sienyte, alkali granite and other rocks containing varying amounts of quartz. All these varieties are more properly labeled as granitoid rocks.

Granitoids are plutonic igneous rocks which, as they cooled, were subject to compression. They were formed when large amounts of magma were trapped below the earth's crust and, not finding a vent to reach the surface, hardened there, at depths between 10 and 500 m. The magma that originated the granitoid had varying alkali and silica content, deriving from the chemical evolution of basic magma from the earth's mantle. As regards their crystalline structure, granitoid rocks may be equigranular (of consistent grain size) or porphyritic (with contrasting sizes of coarse and fine grained crystals). Texture is always holocrystalline, i.e. comprising only minerals. Porphyritic granite arises from two parageneses, below the earth's crust, under different temperature and pressure conditions: one gave rise to large crystals (phenocrysts) with well defined shape, the other to finer-grained minerals without their own habit. On the other hand, equigranular structure is the result of gradual cooling of the batholith, under slowly and regularly evolving pressure and temperature.

As regards their macroscopic structure, granitoids are usually isotropous and very compact.
Color depends on the amount and type of the minerals contained in the rock. The most common are quartz, K-feldspar, plagioclase, mica (muscovite and biotite) and hornblende. When K-feldspar predominates, the rock takes on a reddish color. Quartz and/or plagioclase produce a light color, biotite and hornblende a dark color. Different proportions of the main minerals produce a whole range of intermediate colors. Granitoids can also be of yellow or green color due to the alteration of iron and magnesium minerals into phyllosilicates.

The geology of Sardinia is extensively dominated by large masses of granitoids that make up most of the Sardinian-Corsican terrane. A meridian strip extends from Capo Carbonara (South-Eastern Sardinia) to Corsica, and extensive outcrops are located in the Sulcis-Iglesiente district (South-Western Sardinia).
Commercially quarried Sardinian granitoids formed in the Paleozoic Era, between 310 and 280 million years ago, following the Hercynian Orogeny.
Outcrops exhibiting limited fracturing are found in Central-Northern Sardinia. This is why the largest quarrying operations for building and ornamental stone production are located in the Gallura and Baronie districts.

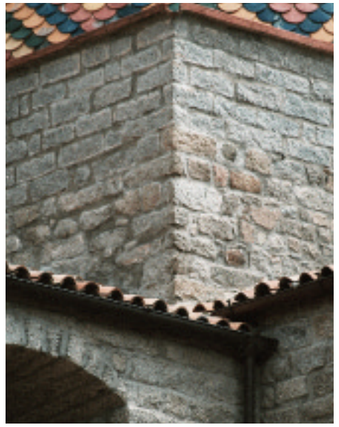
Opposite:

Thin cross-section of a granitoid
Light and dark-colored quartz and feldspar crystals, hornblende and biotite (colored).

Hollowed rocks
Hollowed granite rocks and crystal-clear sea (South-Eastern coast).

Landscape in Gallura
Hollowed rocks, erratic granite boulders and Mediterranean scrub.

The sea of Sardinia
Granite outcrop (SE coast).



Opposite:

Church in split face granite blocks; large sawn slab paving.

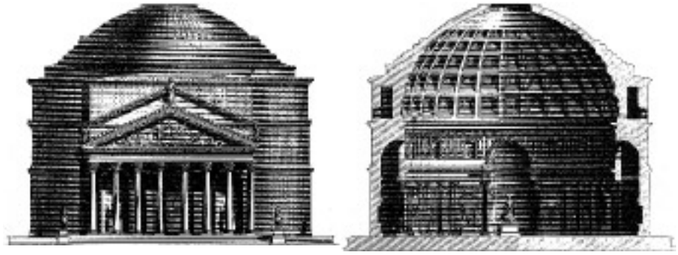
Historical Background

In Sardinia, wherever large granite formations are found, the landscape is dotted with ancient stone monuments, which blend harmoniously with the solitary Nature surrounding them. Granite, painstakingly worked by Nuraghic stonemasons into large blocks and slabs or shaped into monoliths, was the building material for the Nuraghi (megalithic stone fortresses) and 'Tombs of the Giants'. These ancient structures still convey a timeless fascination — such is the magic of stone.

Tombs of the Giants
1800-1200 B C

Bronze-Age sacred monuments, for burials and religious rites. A long corridor bordered by rough-hewn granite boulders leads to the high, dressed monolithic stele.

A small opening at the foot of the stele led to the burial chamber, where the chiefs of the community were buried.



Pantheon
(1st century A.D)

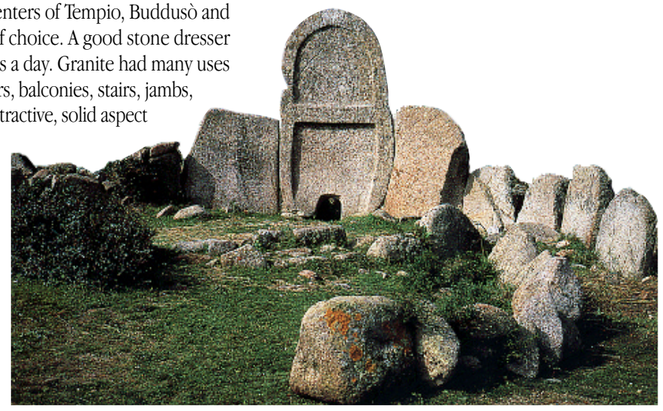
Façade and vertical cross-section.

The Romans used Sardinian Granite to build monuments and patrician villas and to pave roads. In some coastal areas (Capo Testa) we can still make out the signs of the ancient quarries of that time. Granite from Gallura was even used to build some of the columns of the Pantheon in Rome and the colonnade of the Pisa Cathedral (14-15th century).

In the so-called 'Granite towns' i.e. the historic centers of Tempio, Buddusò and many others, granite was the building material of choice. A good stone dresser could produce between 40 and 50 building blocks a day. Granite had many uses in house building (load-bearing walls, lintels, floors, balconies, stairs, jambs, moldings etc.). This beautiful stone imparted an attractive, solid aspect even to the simplest dwellings.

Works of art of all sizes were carved in granite by the Sardinian stonemasons up to the mid 20th century. They included architectural components for churches, buildings and street furniture. These outstanding feats of craftsmanship, almost inimitable now that Sardinian Granite is fabricated with modern automated methods, were skillfully molded with mallet and chisel.

The slightest mistake when striking the mallet could irreparably damage the whole handiwork.



Cala Francese (1880-1938)
Stone dressers at work.

The trolley tracks for transporting the blocks from the quarry face to the ships of the Sardinian Granite Export Co.

Stone dresser at work
The great sphere is entirely hand-carved out of the cubic stone unit. In the photo, the stone dresser, Paolo Balata.

Organized trade in Sardinian Granite started in 1870. The Sardinian Granite Export Company had its head office in Genoa, while the quarry was located on La Maddalena, at Cala Francese. Here, for about half a century there was a large, close-knit community of Sardinian quarrymen and stone dressers, later joined by other workers from Tuscany, Lombardy, Emilia and Piedmont. Granite quarrying and fabrication was to become the most thriving industry of Northern Sardinia. Thanks to its high technical and aesthetic properties as well as its excellent finishing, Sardinian dimension stone soon achieved great success on both national and foreign markets.

Major building projects of the early 20th century using gray-pink granite from La Maddalena include: the base of the Statue of Liberty (New York), the Milan Stock Exchange, the Palatino bridge in Rome, the Tiber river embankment (Rome), the dry docks at Venice, Taranto and Malta, road paving works at Genoa, Naples, Rome and Milan, the monument to D. Guzmao at Santos (Brazil), and a grandiose monument made on a French design, 50 m high and 240 m long, erected at Ismalia (Egypt) to commemorate the defense of the Suez Canal, requiring 4,730 metric tons of granite.

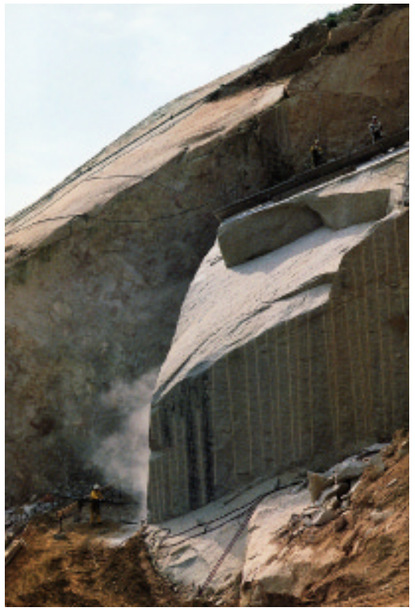
The Cala Francese venture came to an end in the late 1930s, when, like many others, the company was hit by the consequences of the Great Depression that had overtaken the American economy. For the next few decades, the Island's stone production consisted mainly of building stone for the local market. The first Sardinian Granite quarrying and fabrication enterprise officially registered with the Chamber of Commerce was incorporated in Buddusò in 1961. Since then, the Sardinian Granite industry has grown steadily (about 170 quarries are currently active). Modern technology coupled with the island's ancient stone working tradition has enabled Sardinian Granite to account for 75% of Italy's total granite output for a number of years now.

Introduction to Sardinian Granite

The name Granite, ever a synonym of solidity and strength, comes from the Latin *granum*, grain. Indeed its aspect is characterized by coarse grains, visible to the naked eye. Its high crystal density coupled with the large amount of quartz crystals makes it one of the hardest rocks, its hardness being about 75% of that of diamonds.

Sardinian Granites are among the hardest and most resistant of all commercial granites quarried across the world, as well as being of very consistent appearance and uniform color. Add to this the high-quality local fabrication plants, and you will understand why Sardinian Granite is the stone of choice for a wide range of architectural and landscaping applications requiring durability, resistance and aesthetic appeal.

As a commercial term, the word 'Granite' defines a large group of rocks, which may be classified as granitoids. Each type of granite, according to its origin and geologic age has specific physical, and mechanical properties and aesthetic features, making it unique. Whenever an architectural project foreseeing the use of granite (or other natural stone) is planned, the technical characteristics of the stone must be carefully analyzed in order to predict its behavior once installed. In particular,



UNI Standard 8458 (Stone Products) defines granite as follows: "…any compact, polishable phanero-crystalline rock, mainly consisting of mineral of 6 to 7 degree hardness on Mohs' scale".

SARDINIAN GRANITE

- Excellent technical and decorative properties
- Virtually inexhaustible deposits
- Exceptionally consistent texture and color
- State-of-the-art quarrying and fabrication techniques
- Produced in full compliance with safety and environmental requirements
- Applied throughout the world, in widely differing climates

Sardinian Granite offers the best performance in terms of durability and overall strength as compared with the other few types of ornamental stone that can be used to clad large buildings, or as flooring materials for commercial lobbies and walkways. These applications of granite are widespread across the world, and many prestigious cladding and flooring projects have used Sardinian Granite.
The technical characteristics of any natural stone are the result of its geological history. Not all granites exhibit the outstanding characteristics of Sardinian Granite, which ranks as one of the most valuable and ancient natural stones on earth.
Indeed, the rock which gave rise to the various types of Sardinian Granite was set in place about 300 million years ago as a huge granite batholith, which currently appears on the surface on an overall area of more than 6,200 sq km, marking the main event of Sardinia's geological history. The composition of the molten mass which gave rise to the Sardinian batholith, its cooling timeline and the type of forces interacting with it all contributed to creating highly resistant granites, ideal for durable polishing.

1- Mohs' scale classifies all known minerals from the softest to the hardest, and provides a rapid assessment of hardness of an unknown mineral, placing it correctly in the scale.
Some common objects and minerals of known hardness are needed for assessment purposes.

MOHS' SCALE

1.	Talc	
2.	Gypsum	equivalent to the hardness of a fingernail
3.	Calcite	equivalent to the hardness of a coin
4.	Fluorite	
5.	Apatite	equivalent to the hardness of a penknife blade
6.	Orthoclase	equivalent to the hardness of a glass windowpane
7.	Quartz	equivalent to the hardness of a steel wire
8.	Topaz	
9.	Corundum	
10.	Diamond	

Sardinian Granite
Quarrying Districts and Sites

Sardinia comprises five Quarrying Districts, each producing stone with homogeneous petrographic characteristics: of these, four are Granite Districts and the fifth is the Orosei Marble District. Within each district we may further distinguish the quarrying sites, smaller areas where quarries and often fabrication plants are located.

Sardinian Granite Quarrying Districts:

1) ARZACHENA – LUOGOSANTO – 78 operating quarries

Stone type: Granular monzogranite with small (1-2 cm) pink K-feldspar crystals (commercial type: 'Pink Granites').

Quarrying localities: Bassacutena - Luogosanto

2) TEMPIO PAUSANIA – CALANGIANUS – 29 operating quarries

Stone type: Heterogranular monzogranite with large (8-10 cm) pink K-feldspar crystals (commercial type: 'Ghiandone')

Quarrying localities: Monte Nuragone - Luras - Calangianus - Muddizza Piana - Aggius -Tempio Pausania

3) BUDDUSÒ – ALÀ DEI SARDI
27 operating quarries of Sardinian Gray + 23 operating quarries of Sardinian White

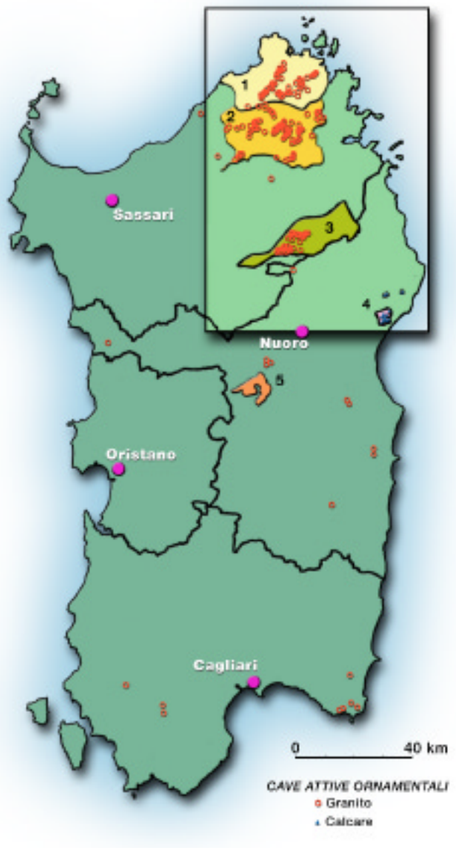
Stone type: Equigranular leucogranite with medium-small (1-3 cm) K-feldspar crystals, plagioclases and light gray quartz (commercial type: 'Gray Granites from Buddusò and Alà dei Sardi' and 'Sardinian White Granite')

Quarrying localities: Alà dei Sardi - Buddusò

5) OVODDA - 2 operating quarries

Stone type: Heterogranular monzogranite with small (>2 cm) of K-feldspar crystals, grey plagioclases and quartz (commercial type: 'Gray Granites from Ovodda').

4) OROSEI MARBLE QUARRYING DISTRICT - 15 operating quarries



ACTIVE DIMENSION STONE QUARRIES
Granite
Limestone

Original map based on data provided by the Sardinia Quarry Office and Progemisa SpA.

In this chapter we shall describe both the granites from these districts and the following two types of granite quarried outside them:

1) commercial type "S. Giacomo Yellow" quarried in an area between the Arzachena-Luogosanto and the Tempio-Calangianus districts - 7 operating quarries.
Stone type: white granite, granular, with small crystals (1-2 cm) of K-feldspar, plagioclase and quartz plus a yellowish component

2) commercial type "Ferula Pink" quarried in the area contiguous to the Orosei Marble District -2 operating quarries.
Stone type: granular monzogranite, with small crystals (1-2 cm) of pink K-feldspar.

The yield/wastage ratio is low for the Ghiandone type (65%) and higher for the other trade types (50%).

The characteristics of a Granite's feldspar crystals provide indications as to the composition of the molten rock which originated it and its cooling rate. Using crystallization diagrams (e.g. of plagioclasic molten rock) that can be drawn up at test laboratories, we see that crystallization starts at about 1370°C.

The Dimension Stone Industry in Sardinia

Granite	
Annual production	~ 300,000 m^3
No. of operating quarries	165
No. of workers employed	1389
Orosei Marble	
Annual production	~ 80,000 m^3
No. of operating quarries	15
No. of workers employed	400

Source: Quarry Office, Region of Sardinia

Quarrying

Past and present
A rusty drill bit, still fixed in the rock of an improvised 'quarry' recalls the period when stone quarrying was not yet regulated by strict environmental protection rules.

Quarrying
Before opening a Granite quarry or starting to work on a new rock face, an accurate geological survey is required to gauge the structure and compactness of the deposit. This survey, which is the key to optimum yield, is supported by statistical and mapping data, and is based upon a number of different exploration techniques: sonic methods (these exploit the propagation speed of an 'ad hoc' compression wave generated between a point on the surface and the geophones: the petrographic scheme thus obtained provides information on the degree of fissuring in the portion of the deposit being examined, since wave speed is a function of the nature of the rock); electrical methods (they measure apparent soil resistivity, a datum that in a granite deposit is influenced mostly by the amount of clay, which is lower in more compact rock); electromagnetic methods (VLF), and sampling methods (well logging) to identify the color and texture of the rock and identify any unwanted minerals, such as pyrite.

The layout of the deposit affects the choice of quarrying method. Sardinian Granite is quarried by means of cutting, so as to obtain blocks of regular size, dividing the rock face into levels, benches and horizontal ledges (for horizontal quarrying operations) or into vertical slices (when the deposit is arranged vertically, with dome outcrop).

Whenever a quarrying site is selected, the first step is to even out the rock face. A hand operated drill is used to stitch-drill the whole top length of the rock face: the holes are filled with explosive which is then detonated. The rock face is now even: the next step is making two side cuts with a diamond wire saw. This method has long replaced older block extraction techniques in all the main quarries in Sardinia. Diamond wire cutting makes it possible to cut the block vertically (up to 9 m): the wire consists of a steel carrier cable on which 11 mm synthetic diamond beads are fixed, alternating with spacers.

If neither diamond wire nor blasting are feasible, when for example there are special internal tensions in the rock mass, thermal lance cutting is used (1,200 °C) with a jet burner. However, during flame cutting all other quarry activities must be stopped; moreover this technique is slower than diamond wire cutting (cutting speed is 1.5 m^2/hour compared with 3-5m^2/hour) and is less advisable in terms

Loaf toppling

The initial cutting stages of the stone loaf are among the most critical. The diamond wire must follow an angular course, under high tension, a process requiring great care by the equipment operator.

On an average, for cuts of about 100 sq m, it takes almost 2 hours for the wire to reach its working position, making the cut along an arched line.

of health and safety, due to the combustion gases and loud noise (about 120 db) caused by the flame. Another technique – little used however – is water-jet cutting, whose performance in granite quarrying has proved unsatisfactory.

"The machine helps, but the stone is master", is a common saying among natural stone quarriers and fabricators. What this means is that knowing the natural bedding and cleavage planes of the deposit is paramount in ensuring the quality of the quarried stone and the entire production cycle.

Thus, quarriers must be expert and sensitive to the various nuances of quarrying operations and companies must invest in innovation and in work-place safety.

All these requirements are fully met by the Sardinian Granite industry, where technicians are highly skilled, often true masters of the art of quarrying, operating in a safe and healthy work environment.

Cutting the Primary Block

To cut the quarry block from the rock mass, two converging bore holes are made, one vertical, the other horizontal, intersecting the first. The diamond wire is strung through the holes. The horizontal hole is made with a down-the-hole hammer while the vertical one is made with a hammer drill equipped with a steel drill bit measuring between 40 cm and 12 m in length. As drilling proceeds, progressively longer drill bits are used.
The diamond wire cutting process is entirely automated. The technician controls the various steps on a control panel. The cutting equipment, consisting mainly

of a flywheel, is mounted on a platform that advances on a rail track. The wire is sent back by means of pulleys. Their number and set up depend on the space available for cutting operations, which can be very limited.

When the diamond wire cannot be used for horizontal cutting of the quarry block, the older blasting system is used. A series of holes is stitch-drilled to a depth of about 7 m, using a monoblock drill bit; the holes are then filled with explosive.
The blast line must be prepared very carefully to obtain a precise blast and avoid damaging the block (usually, every blast round involves the cutting of two or at times three blocks). The filling and blasting operation can only be carried out by a certified explosives operator, whose license is renewed annually.
After the blast, the primary block is toppled onto a loader, which in the best equipped quarries can carry up to 6 cu m of rock. Once toppled, the primary block is firstly inspected to check for any fractures before further cutting. A number of tools can be used to topple the block (inflatable bags, hydraulic jacks). They can also be set up so as to affect the direction of the block's fall. The most expert technicians are able to detach the primary block from the quarry ledge by dragging it, using a derrick so as to avoid the slightest damage to the stone. Being a natural stone, granite may display variations in color and texture also within a single area of the same quarry. However, the likelihood of such variations can be minimized by appropriate exploration and quarrying techniques.

Squaring the Blocks

Examination of the toppled primary block provides indications on how to better divide it into mill blocks. Cutting parameters can be selected so as to obtain the greatest number of flawless mill blocks. These are usually of standard size, unless otherwise requested by the buyer. To obtain mill blocks, cutting lines are traced by pencil on the primary block and holes are stitch-drilled with a block cutter with two drillers, each equipped with a monoblock drill bit. Water flows inside the holes so as to keep dust emissions to a minimum The blocks are then detached with the plug and feather method, i.e. driving metallic wedges into each hole. Granite quarrying and

Block squaring

Cutting the loaf into blocks is performed by means of a light block-cutting machine, equipped with a monoblock drill bit.

The aim is to obtain the greatest possible number of mill blocks. In this stage the stone is carefully inspected for defects such as veins, etc.

Block handling
This front-end loader can carry blocks weighing over 3 tons (1 m3 of granite weighs about 30 q)

fabrication are more costly compared to that of other dimension stones. In fact, all machinery and tools are more expensive, wear out more quickly and have a lower productivity rate than those for other types of stone, such as marble.

The quarry blocks are placed on trailer trucks by means of front-end loaders for shipping to their destinations. They are in part sold as mill blocks in mainland Italy or abroad. Others are locally fabricated into semi-finished products (slabs and strips of varying thicknesses) and finished products (sawn products, split products, dimension stone for various architectural and landscaping applications).

Transport of the blocks
Road hauling of stone blocks is subject to precise regulations defining mode and means of transport according to block weight.

From the brief description above, it is clear that great professional skill is necessary to ensure the highest levels of worker safety and appropriate material selection in all quarrying phases. Sardinian Granite quarries make the best use of modern extraction technology. The whole natural stone industry of Sardinia — heir to a long tradition of stone working — has adopted advanced production methods. Indeed, a number of quarries and fabrication plants are already certified in accordance with ISO 9000 and ISO 14000 international standards. Exceptional technical and decorative properties are not the only key to the success of Sardinian Granite: they have been coupled with state-of-the-art processing to make this stone a world leader for quality cladding and paving applications in major projects in widely differing environments and climates.

Chapter 1 - Sardinian Granite - *Quarrying and Fabrication*

Sawing with the block-cutting machine
Vertical cutting of strips.

Fabrication

Only perfectly whole blocks are selected for sawing.

The blocks are cut by means of gangsaw or diamond saw, to obtain slabs and strips. Gangsawn slabs have a minimum standard thickness of 15 mm, though 18 mm is more common. However, standard commercial slab thicknesses are usually 20 or 30 mm.

Strips are obtained by diamond sawing, using multi disk saws with up to 25 diamond blades of 60 cm diameter. After completing the vertical cut, another blade (about 20 cm in diameter) makes the horizontal cut to free the strips. Minimum nominal thickness of strips is 12 mm. After gauging, actual thickness becomes 10 mm.
For thicknesses of 10 mm , the size of the articles obtained from the strips (usually floor and wall tiles) should not exceed 30x30 cm. This is because, for larger sizes the stress borne by the strips (surface finishing on one face, thickness gauging on the other) could bend the tiles. As a consequence the installed tiles would not be perfectly level, with obvious technical and commercial drawbacks. Therefore, for larger tiles, thicknesses should be increased as follows: for 40x40 cm tiles, mm 13; for larger tiles obtained with diamond sawing, such as 50x50 and 60x60 cm tiles, minimum finished thickness should be 15 mm. Trimmed slabs can also be obtained from gangsawn slabs. However, these slabs are generally used to produce other finished products (standard articles), of maximum sizes up to 125x125 cm and thicknesses ranging between 1.5 and 30 cm.

The following page shows the tile line, where strips are cut into floor tiles, using a cross-cutting machine equipped with two diamond blades that make parallel cross-cuts according to the size chosen.

Sawn products are obtained from sawn slabs, strips and thicknesses. On the other hand, rough blocks having specific structural properties are used to obtain rough thicknesses from which split-face articles are made.

Cross-cutting machine
Floor tile line

Slab handling
In the background, the slab polishing machine, able to hone and polish 1,000 m2/day of granite (1000 slabs/8h).

Cutting phases
The control screen of the block-cutting software.

Chapter 1 - Sardinian Granite - *Quarrying and Fabrication*

Surface Finishes

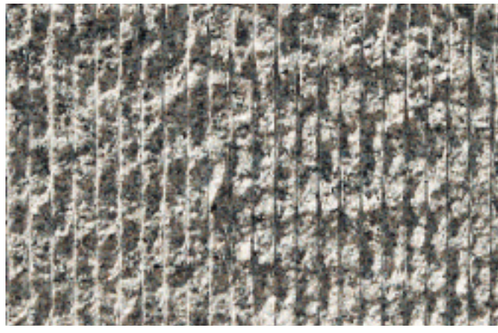
Surface finishes of Granite products are chosen on the basis of their intended use and the aesthetic effect desired.

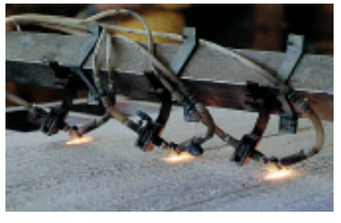
Polished
Polishing enhances color intensity, provides a high and lasting gloss and makes the surface of the stone element perfectly and uniformly smooth, increasing its resistance to weathering. Polishing is achieved by a machine equipped with a number of grinding wheels (carborundum) mounted on a rotating head that runs along the whole length of the conveyor belt, at the end of which are the mandrels for mirror polishing.
Sardinian Granite floors can also be polished after installation, and the operation can be repeated whenever necessary, without altering tile thickness. However, elevated floors cannot be polished or re-polished, due to the amount of water necessary for the operation. The degree of polishing depends on the buyer's glassiness requirements.

Polished surfaces in Sardinian Granite, thanks to the excellent technical properties of this stone, retain their high-gloss finish also when exposed to weathering agents. Conversely, other types of commercial granite, geologically younger than the Sardinian ones, weather more easily; this means that their polished finish can become opaque and at times the original color is altered, especially when they are applied to external surfaces.

Flamed Finish (Thermal Finish)
A flamed or thermal finish is a rough, non-slip finish, suitable for external paving applications subject to medium to heavy traffic (coarse-flamed finish) or for interior walkways, sills and stairs (medium and fine-flamed finish). The heat from the adjustable acetylene torch, makes more uniform the color and pattern of the surface crystalline structure, which takes on a typical vitreous and translucent aspect.

Bushhammered
Bushhammering achieves a textured, non-slip finish, suited for driveways, flights of steps, sills, road strips etc. In the past, stone masons wielded the bushhammer



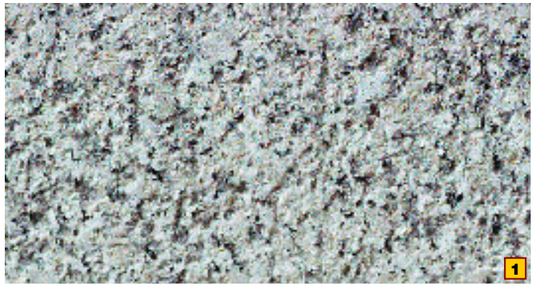


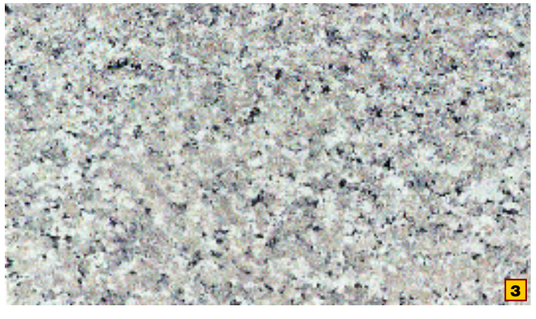
Non-standard finish
Coarse-combed large slab for external surfaces subject to heavy traffic. This textured finish is obtained by rough-hewing the sawn surface.

Honing and polishing lines
Automatic slab loader with suction cups.

Flaming line

1) Flamed finish
2) Bushhammered finish
3) Saw-planed finish





by hand. It was a tool with metal points, whose sizes determined the degree of texturing obtained. Nowadays, with the exception of a few hand-made stone products, bushhammering is most commonly performed by pneumatic hammers, equipped with multi-pointed chisels with sharp tungsten points.
The resulting texturing can be coarse, medium or fine, depending on the chosen depth of the picking (see p. 205).

Sandblasted

This finish achieves a matte-textured, moderately non-slip surface, with homogeneous, warmly diffused color. Sandblasting is accomplished by exposing the surface to a steady flow of sand at adjustable pressure.

The pictures show the most common finishes for Sardinian Granite. Upon request, other finishes may also be provided (acid-washed, chiseled etc.).

Blocks

Blocks usually range in size from 7 to 10 commercial m^3, and weigh from 230 to 220 quintals.

Most quarry cuts are done with diamond wire (70%) which achieves perfectly squared blocks, free from the tiniest imperfections.

ROUGH BLOCKS - *Dimensions (cm)*	
1st grade rough blocks	
Height	130 - 205
Length	230 - 350/380*
Width	130 - 230

** Greater lengths can be supplied on request.*

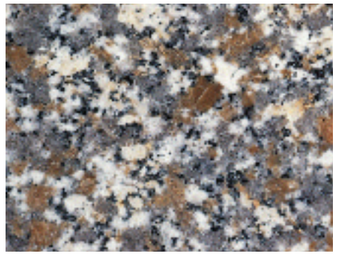
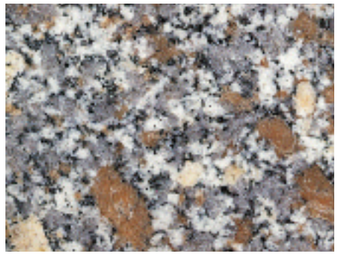
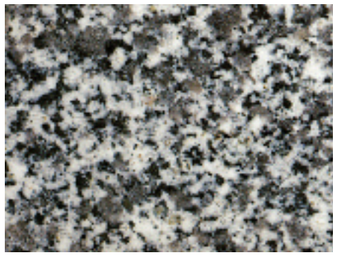
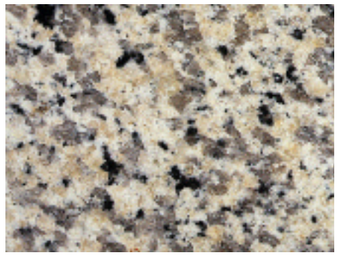
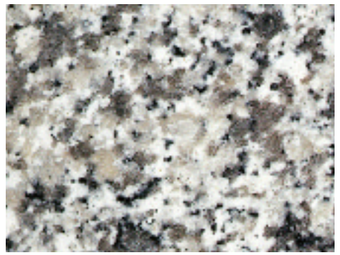
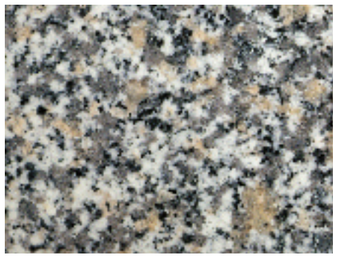
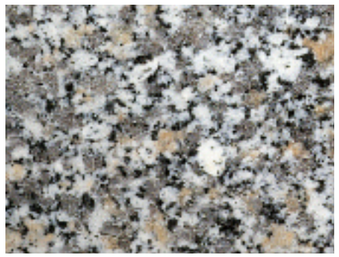
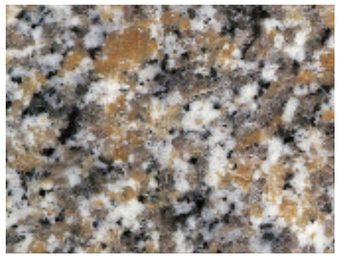
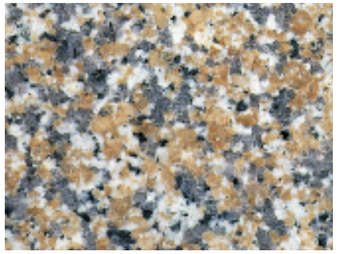
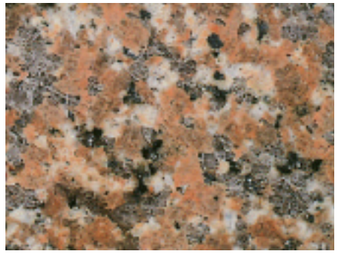
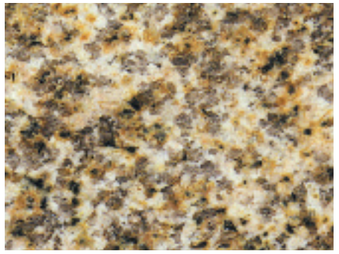
At least 70% of cuts are made by means of diamond wire.
Price per cu m may vary depending on the quarry face and block cutting characteristics.

2nd and 3rd grade rough blocks

Second grade blocks have the following general characteristics: height, length and width: values below the minimum for 1st grade blocks. They may have color inconsistencies and/or textural imperfections.
At least 70% of cuts are made by means of diamond wire.
Price per cu m may vary depending on the quarry face and block cutting characteristics.
Third grade blocks may have the above mentioned defects, concurrently and to a greater degree.

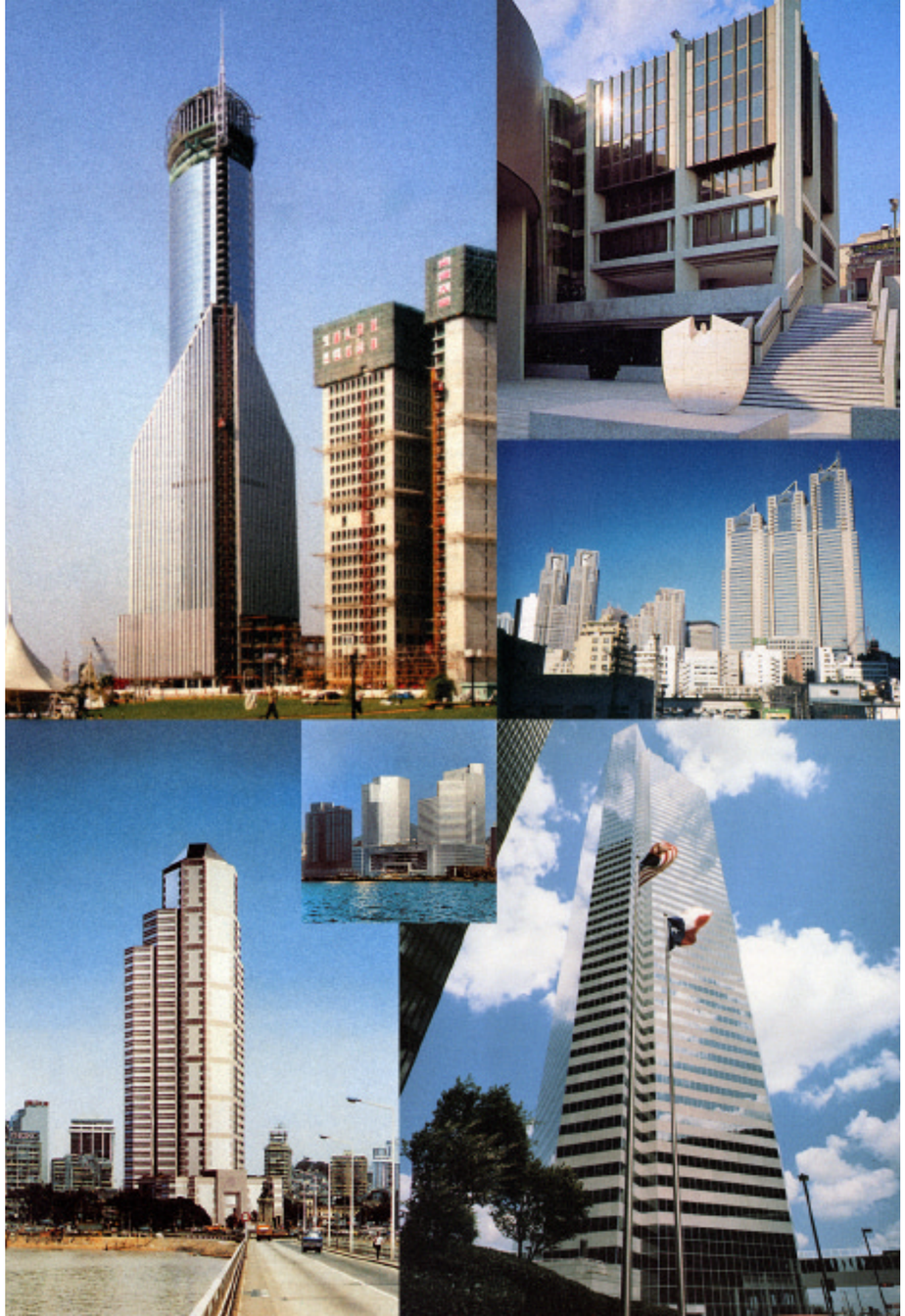
SLABS - *Sizes (cm)*	
Thickness	from 2 to 30 (greater on request)
Length	min 230/max 380 (depending on the block)
Width	min 120/max 250
Surfaces	sawn - polished - flamed - bushhammered sandblasted - acid washed

STRIPS - *Sizes (cm)*	
Thickness	1 - 2 - 3 - 4
Length	min 230/max 350 (depending on the block)
Width	min 1/max 40 (greater on request)
Surfaces	sawn - polished - flamed - bushhammered sandblasted - acid washed

Left to right:

Ghiandone Gallura
Ghiandone Limbara
Malaga Gray
Nuraghe Gray
Pearl Gray
Antique Pink
Beta Pink
Cinzia Pink
Nule Pink
Ferula Pink
S. Giacomo Yellow



SARDINIAN GRANITE

SAWN PRODUCTS

External Cladding of Large Buildings

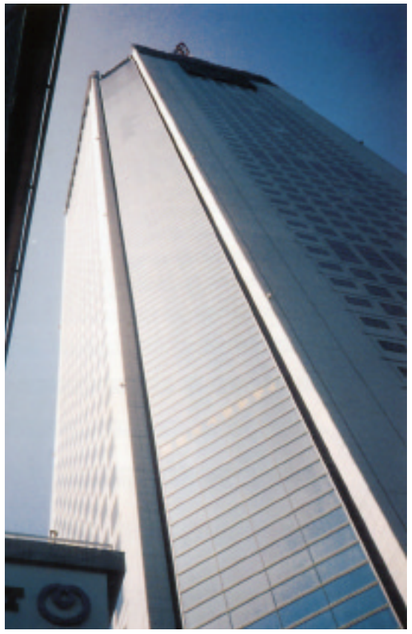
External Wall Facing

External Paving

Flooring

Architectural Features and Details

Street Furniture



External Cladding of Large Buildings

The photographs on these pages show some examples of cladding projects with Sardinian Granite in the five continents, in widely differing climates.
The technical properties of Sardinian Granite, combined with the great skill of quarrymen and technicians make it possible to produce extra-thin veneer stone. Thus the exterior facing adds comparatively little weight to the structure (however, for structural reasons, the minimum thickness of cladding panels is usually 3 cm). The panels are perfectly dimensioned and gauged, ensuring ease of assembly onto backing and support structures.
Stone for cladding large buildings is usually polished or flame finished. The same cladding project may often combine elements with different finishes. Flame finish is preferred if one wishes to avoid the mirroring of light by polished surfaces, which in very tall buildings may impair vision of the topmost part of the structure.
The technical properties of granite for cladding applications are carefully measured. They include in particular: flexural strength, linear thermal dilation coefficient and impact resistance.

Above:
Skyscraper built in a highly seismic zone (Miami - USA) and clad with Sardinian Pearl Gray Granite. This granite was selected from a number of granites from all over the world, because of its unique technical properties and consistent color. Thickness of the cladding panels is 4.5 cm.

Cladding of large buildings

Thanks to its physical and mechanical properties, Sardinian Granite can be worked into variously sized panels meeting any type of wall cladding requirement (resin-coated and screened slabs, for ventilated and non-ventilated external walls). The cladding panels are precision-sized for ease of installation.

Sardinian Granite is highly appreciated by architects and by suppliers of clamping and anchoring systems; on large projects, the latter work in close contact with the stone fabricators. Although cladding has a decorative purpose (resulting from the color, fabric, texture and surface finish of the stone), when designing the panel and its anchoring system

continued on page 32

Chapter 1 - Sardinian Granite - *Sawn Products*

Some major cladding projects using Sardinian Granite

Tokyo (Japan)	Tokyo City Skyscraper
Ottawa (Canada)	Metropolitan Life Building
Brisbane (Australia)	Riverside Center
Sidney (Australia)	Bond Building
New York (U.S.A.)	Financial Square
Englewood (U.S.A.)	Plaza Tower One
Miami (U.S.A.)	Southeast Financial
Seattle (U.S.A.)	First Pacific Center
Houston (U.S.A.)	Gulf Tower
London (U.K.)	Westminster Bank
Cologne (Germany)	Restoration of the Cathedral
Wanchal (Hong Kong)	Hong Kong Convention and Exhibition Center
Jeddah (Arab Emirates)	Royal State Palace
Istanbul (Turkey)	Conrad International Hotel
Manila (Philippines)	Asian Development Bank
Calgary (Canada)	Trizec Towers
Hartford (U.S.A.)	North East Plaza
Hong Kong (China)	New Standard Chartered
Oslo (Norway)	Aker Brigge
Bergen (Norway)	Bergen Commercial Building
Brussels (Belgium)	Toyota Head Office
Rome (Italy)	Ministero delle Poste e Telecomunicazioni
Brussels (Belgium)	Banco di Roma
Stuttgart (Germany)	Daimler Benz Museum
Singapore	Toa Payoh and Novena Underground Station
Frankfurt (Germany)	Der Odertun
Frankfurt (Germany)	Atricum
Macao (China)	Bank of China
Jeddah (Saudi Arabia)	El khayyatt Building

External Wall Facing

Sardinian Granite is a superbly workable, highly versatile stone. Thin sawn and polished panels can be used to face large engineering projects and city buildings of various styles.

Alternatively, thick, split-faced elements enhance the Mediterranean nature of this stone and are perfect to harmonize fine resort developments with the stunning nature surrounding them. Sawn tiles are used to face external walls of city buildings, usually with polished or flame finished surface, and sharp or chamfered (rounded) edges.

The photographs show some of the many applications in private and public buildings of sawn and polished tiles and panels.

For interior wall facing, where light weight is a prime consideration (boats, elevators, car dashboards), Sardinian Granite can be produced in extra thin

Chapter 1 - Sardinian Granite - *Sawn Products*

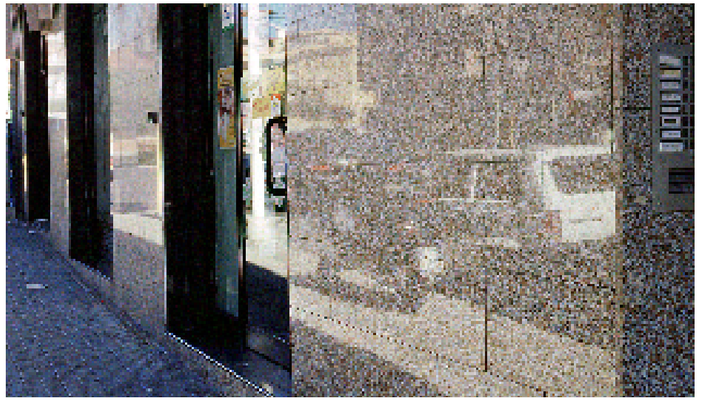
Standard size tiles
As defined by the UNI 8458 standard.

TILES - *Standard sizes (mm)*

(Interior and external facings - internal floorings).

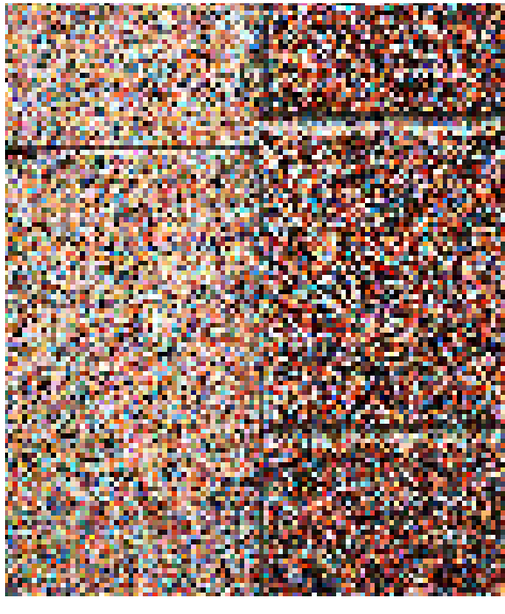
Side x side	thickness
300x300	10-12-15-18-20-30
305x305	10 (American and Japanese markets) -15-18-20-30
400x400	13-15-18-20-30
457x457	13 (American and Japanese markets) -15-18-20-30
600x300	13-15-18-20-30
500x500	18-20-30
600x600	18-20-30
610x610	15-18

All intermediate sizes available, in square or rectangular shapes, up to a maximum thickness of 40 mm. All sizes can also be supplied gauged, trimmed, and/or with chamfered edges.
Standard commercial tolerances (mm): thickness ±2 - sides ±2 – flatness ±2. Calibrated tile tolerances (mm): thickness ±1 - sides ±1 - flatness ±0,8. Face finish: to order.
Packaging: in sealed cartons containing slabs packed in sheets of polystyrene, maximum 10 units of 300x300x10 mm size and 4 units of 610x610 mm size. Transport by trailer truck: on 40 sq m wooden pallet, complete with shrink wrapping. Transport by container: 30 sq m crates.



Edge finishing
Finishing of the edges with a 45 degree angle enables workmanlike installation and jointing.

Edge chamfering
This consists of smoothing sharp edges (which mark the joint between tiles). This technique avoids accidental chipping of the edges during installation.



Cladding of large buildings

Installation of Sardinian Granite panels on the external wall of a Tokyo city skyscraper.
The panels are cut to size in the building yard and are then secured to an anchoring framework preset on the building, sized and prepared for housing the panels. Between the backing and the panels there is an airspace where an insulation course is placed. The stone panels are thus not bonded to the building but "work" independently from it in all respects.

veneers. Indeed, its physical and mechanical properties allow production of resin-coated tiles just 5 mm thick (for sizes: 300x150 cm) or 7 mm (sizes: 250x130 cm). Precision cutting can also be carried out in the building yard.

Sardinian Granite is also marketed in U.S. chain stores, where it is possible to buy packages of polished, gauged and chamfered tiles, measuring 11x7.5 cm and 1 cm thick, ready for use in DIY applications.

continued from page 28

a number of related technical aspects must be taken into account: height of the building; size of the stone panels; weight of the cladding; choice of joints (open or closed); thermal expansion of the materials; distance of the cladding from the backing wall; wind loads (bending and flexural); geo-climatic features; local seismic risk value; presence of pollutants such as acid rain etc.

Panel weight exerts vertical forces while wind subjects the entire surface of the panel to horizontal forces. This is why the stone must have excellent technical properties, especially as regards flexural strength. The anchoring devices are also subject to wind loads, and must be sized according to their intensity. As regards panel thickness, there are no common international standards. In general terms, minimum panel thickness for installation with anchoring systems should be 3 cm (in the U.S. a minimum thickness of 2.5 cm is allowed). As regards specifications for cladding and veneer stone there is no internationally accepted standard. Each country applies national specifications (Italy: UNI; Germany: DIN; United Kingdom: BS-British Standard). The U.S. standard, A.S.T.M., is normally used as the reference for international projects. It defines the tests to which the stone samples must be subjected. A unified European Standard for regulating the industry throughout the EU is currently being drafted.

There are four main systems for connecting the cladding panels to the backing, i.e.: point, linear, continuous and frame systems.

Opposite:

Paving in historic centers

Paving in flamed granite slabs and natural cobblestones.

Square paved with fine-picked granite slabs (50x100 cm).

Chapter 1 - Sardinian Granite - *Sawn Products*

External Paving

Urban paving applications using Sardinian Granite have an attractive, solid aspect and are remarkably durable.
Sawn paving elements — tiles, slabs, large pavers and roughback paving units – can be used for any type of urban paving and are highly resistant to vehicle and foot traffic. All commercial types of Sardinian Granite are extremely resistant to wear and have a high compression breaking load, which is almost unchanged after freeze/thaw cycles. These properties, as well as its high flexural strength, make granite the material of choice for areas subjected to strong changes in temperature. Thickness of the paving units is selected according to the load-bearing properties desired. Their shape, size and finishes may vary according to the designer's specifications.

GRANITE PAVINGS - *Sizes (cm)*

Thickness	Load
2 - 5	pedestrian and cycle traffic
6 - 8	light to medium vehicle traffic
10 - 20	heavy vehicle traffic

Sawn Paving Stone

Square or rectangular pavers, with sawn edges and sizes ranging from 30x30 to 120x60 cm — all intermediate sizes are available. Thickness ranges from 1.5 to 30 cm. Arrises can be raw, smoothed or chamfered. The length of the rectangular units, which is usually almost double their width, can be running or defined according to standard specifications. The top surface of paving units can be rough-sawn, coarsely-honed, flamed, bushhammered or acid washed.

Paving of historical centers

Flamed granite slabs and split face cubes.

Flamed granite slabs and natural cobblestones.

Chapter 1 - Sardinian Granite - *Sawn Products*

Flamed granite slabs

In this example, the slabs are combined with antique finished granite cobblestones (industrial production). The attractive reddish color derives from the surface oxidation of the yellowish component of this kind of Granite, caused by the thermal finish (>1000 °C).

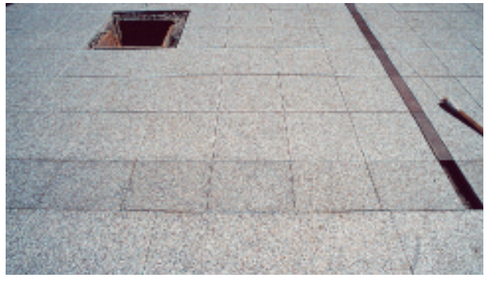
This paving arrangement is distinguished by very thin joints and large units arranged in circular patterns, enhancing the beauty of this masterfully planned and laid out small square. The low steps that frame the square/ lookout have bullnose edges and recessed risers.

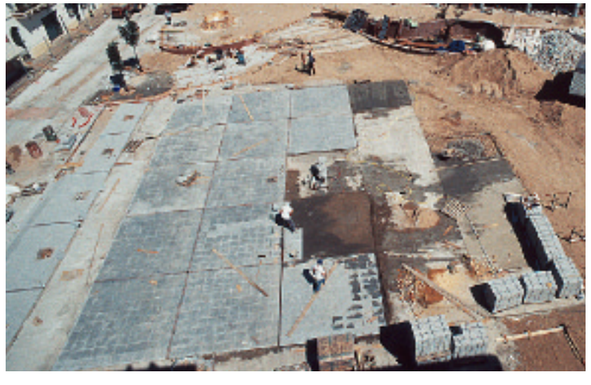
Paving of historical center area

Rough slabs of gray granite of varying lengths and widths, laid out in a random pattern, so as to optimize their use. In this layout, the position of the joints cannot be planned in advance, but is rather left to the workman's craftsmanship.

Paving of a square

Installation of flamed granite tiles (thickness cm 3).





Opposite:

Small square

Paved with bushhammered slabs of gray granite; the large step running round the edge of the square is coarse bushhammered.

Paving Tiles

Paving tiles are generally used for pedestrian areas and cycling paths. Minimum size is 20x20 cm, minimum thickness 2 cm. The sides are sawn, with sharp or smoothed edges. Upon request, other sizes and thicknesses may be supplied, as well as different surface finishes (bushhammered, flamed, etc.).
Tiles are often used in combination with other types of stone units. In the photo of a square being re-paved, both tiles and small cubes are used).

Chapter 1 - Sardinian Granite - *Sawn Products*

Large Granite pavers

The stone units shown in the photo, temporarily removed for road restoration works, were originally laid in the late 19th century.

LARGE PAVERS AND ROUGHBACK PAVING STONES - *Sizes (cm)*

	Large pavers	Roughback paving stones
Side x side	50x100	50x100
Thickness	15	15
Sides	sawn	sawn
Edges	sharp	sharp
Face	coarse bushhammered	rough-flamed
Back	sawn	quarry split

Rough thicknesses

These can be sawn to obtain large pavers and roughback paving stones.

Paving in roughback stone

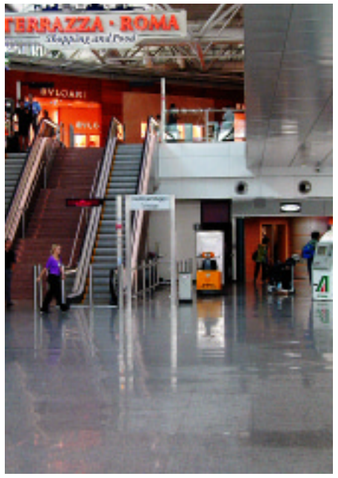
In this case the edges have been worked so as to obtain very marked rough joints. The other paving units are basalt and Orosei marble slabs.

Roughback pavers on a pallet

On the quarry-split back we can see the drill bit marks from the block-squaring process. The face is flamed or bushhammered.

Large Pavers and Roughback Stone

These extremely resistant paving units, able to withstand heavy loads and intense wear, are ideal for roads with heavy vehicle traffic, as well as for piers, industrial traffic areas etc. The pavers are obtained from thick sawn slabs (15 cm min.) that are then sawn to size and finished on the wearing surface. Roughback stones are obtained from the stone left over from primary block production. Their lower surface is therefore still rough split, and shows the drill marks. Roughbacks and large pavers are the modern version of the solid Sardinian Granite slabs (*tacchi*), which were used long ago by the Romans. In the second half of the 19th century, they were used to pave the roads and streets of large cities, and are still to be seen in Rome, Milan, Genoa, Cagliari and Naples.



Flooring

Tiles

Tiles are thin, trimmed flooring units, rectangular or square, usually polished. They are recommended wherever a durably shiny and stylish floor is required. They are the flooring material of choice for commercial lobbies, corridors and indoor recreational areas. Floors covered with Sardinian Granite are extremely resistant to wear, compression and shocks, and do not deteriorate as a result of the passage of trolleys and electrical service vehicles. Their polished finish is also highly durable, and very easy to clean.

The tiles can be supplied already polished or unfinished (sawn and rough-dressed). In the latter case, they are polished, on flat or curved surfaces, after installation. Minimum tile size is 15x30 cm, maximum 60x61 cm. Minimum thickness is 0.8 cm. The sides are sawn, edges are usually chamfered. Tiles can be supplied cut to size according to shop drawings, gauged and with tolerances as shown in the table on page 31. Often, different finishes are combined on the same floor (polished, flamed, sandblasted tiles), both for aesthetic appeal and to create non-slip surfaces.

Multicolored floorings

The strong colors of some “exotic” granites are appealing, but their color and structural consistency are usually limited to small sections of the quarried deposit. This limits their use as flooring material on large surfaces.

Some major buildings recently floored with Sardinian Granite are: Leonardo da Vinci Airport and Termini Railway Station (Rome); Osaka Airport (Japan); Olbia Airport (Sardinia).

Elevated Floors

Elevated floors, already used by the Etruscan and the Romans, require the use of perfectly modular, mobile elements. For this type of application, square or rectangular tiles in Sardinian Granite are supplied. The mechanical supporting structure is usually square and matches tile sizes - 50x50 or 60x60 cm. Tile thickness depends on their size and type of supporting structure (gypsum, honeycomb or aluminum). If thickness is determined by the granite only, gauged thickness of 3 cm is selected, with the following tolerances: thickness ± 0.8 mm; sides ± 0.8 mm; flatness ± 0.6 mm. Elevated floors in Sardinian Granite guarantee:

- Excellent flexural and ultimate strength.
- High color and pattern consistency (an important requirement for large interior floors, whether at ground floor level or elevated).
- High durability of the floor’s polishing and structural integrity (greater than any other natural stone).
- Solid, safe and pleasant walking surfaces, also in terms of acoustic effect.
- Non-static and non-flammable surfaces.

Tread types
Three different types of tread edges. From the top: square edge, bird's beak, bullnose). The different types of treads are shown on page 217.

Interior detail
Four large steps (risers in 'Absolute Black' South African Granite) give rhythm to the polished Gray Granite paving.

Chapter 1 - Sardinian Granite - *Sawn Products*

Architectural Features and Details

Architectural Details

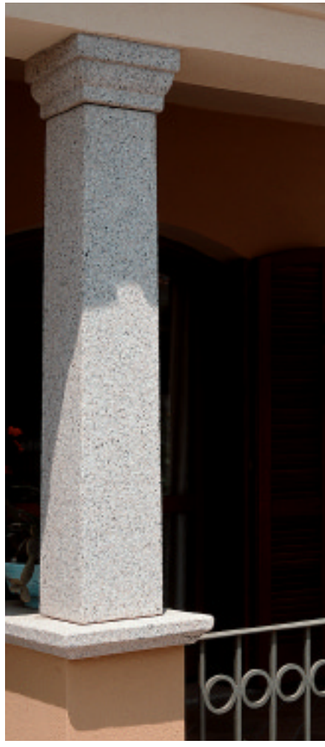
The photographs show examples of staircases made in polished Sardinian Granite. In photo 1, opposite, a staircase with square edge, projecting tread and recessed riser. The staircase is flanked by a stepped skirting. The treads are gauged to the required thickness, with standard width 5 cm. Size, surface and edge finishing can be selected as per customer's specifications.

Granite skirtings can have other uses besides complementing staircases. When measuring more than 15 cm in height, they can be used as decorative base courses, most often on external perimeter walls. Skirtings are supplied with running or precut lengths, surface finish and side shape as requested and usually with sharp edges.

Architectural Features

Sardinian Granite can also be shaped into a wide array of architectural elements (jambs, pillars and capitals, balustrades, cornices, balconies, scarp walls etc.). To dress objects with curved surfaces or relief patterns, the contour-shaping machine, equipped with a diamond blade mounted on a mechanical arm is used. Products obtained in this way often require hand finishing, for instance, smoothing of corners, usually with a grinding wheel or with hand tools.

Hand-carved granite
Some examples of excellent craftsmanship, enhancing the high workability of granite which allows the designer almost total creative freedom.



Bushhammered bollards

Obtained from cubic stone, they can be supplied in various shapes and sizes.

Chapter 1 - Sardinian Granite - *Sawn Products*

Gray Granite pillar

Made of round-section hollow units of different lengths, obtained from cubic stone and inserted on a 3-inch steel core supporting the load of an elevated floor.

Half-round units

Used to finish and protect the base of cylindrical load-bearing structures (masonry columns, lamp-posts, etc)

Fabrication of a planting tub.

Statue in Ferula Pink Granite.

Sardinian Granite is used for a wide range of street furniture and landscaping applications of all shapes and sizes: bollards, planters, benches, bases, fountains, statues, boundary stones) as well as residential applications (countertops, vanity tops, fireplace surrounds, etc.).

Example of Supply Specifications

External Paving in Sardinian Granite Slabs

Supply and installation of ***Sardinian Granite*** paving, ***in slabs of running length, measuring 20 cm in height and 6 cm in thickness, with rough-flamed face, sawn back, sides sawn to 90 degrees and smoothed edges (smoothing of sharp arrises).*** The paving shall be installed, according to project drawings, on a 6 cm-thick cement mortar base course, in the ratio 250 kg type R 3.25 cement to 1 cu m of sand of the appropriate grain size.

Supply price shall include the following work: supply and laying of the base course with a surface cement coating – not less than 6 kg/sq m; establishment of the required gradient for rainwater drainage; vibrating; replacement as needed of any slabs broken or chipped during laying; sealing of the joints with cement grout and sand; subsequent surface cleaning with sawdust, cutting, trimming and any other operation required for workmanlike execution.

Cost Euro/m² (excluding preparation of sub-base)

External Paving in Sardinian Granite Tiles

Supply and installation ***of Sardinian Granite*** paving, ***in tiles measuring 25x25 cm, thickness 3 cm, with rough-flamed face, sawn back, sides sawn to 90 degrees and sharp edges.*** The paving shall be installed, according to project drawings, on a 6 cm-thick cement mortar base course, with the following composition: 250 kg of type R 3.25 cement to 1 cu m of sand of the appropriate grain size.

Supply price shall include the following work: supply and laying of the base course with a surface cement coating – not less than 6 kg/sq m; establishment of the required gradient for rainwater drainage; vibrating; replacement as needed of any tiles broken or chipped during laying; sealing of the joints with cement grout and sand; subsequent surface cleaning with sawdust, cutting, trimming and any other operation required for a workmanlike execution.

Cost Euro/m² (excluding preparation of sub-base)

External Paving in Roughback Sardinian Granite Units

Supply and installation of ***Sardinian granite*** paving, ***in roughback paving stones measuring (side x side) 50x100 cm, thickness 15 cm, rough-bushhammered face, quarry-split back, sides sawn to 90 degrees and sharp edges.*** The paving shall be installed, according to project drawings, on a cement mortar base course of minimum thickness 10 cm with the following composition: 250 kg of type R 3.25 cement to 1 cu m of sand of the appropriate grain size.

Supply price shall include the following work: supply and laying of the base course with a surface cement coating – not less than 6 kg/sq m; establishment of the required gradient for rainwater drainage; vibrating; replacement as needed of any roughback paving stones broken or chipped during laying; sealing of the joints with cement grout and sand; subsequent surface cleaning with sawdust, cutting, trimming and any other operation required for a workmanlike execution.

Cost Euro/m² (excluding preparation of sub-base)

SARDINIAN GRANITE

SPLIT FACE PRODUCTS

Masonry Stone
External Wall Facings
External Paving
Architectural Features and Details
Hand-worked Granite
Street Furniture

Pillars
Obtained by splitting from cubic stone units. The standard type has square cross-section measuring 25x25 cm, maximum height 200 cm and sharp edges. Used as structural and architectural components for high-class residential applications.

Brick-sized blocks
Production process of these indestructible masonry blocks entirely handmade from large rough units, according to a long standing tradition.

Split face Sardinian Granite

Thanks to its extreme hardness and easy cleavage planes, Sardinian Granite can be easily split mechanically. However, the fabricator must be skilled in identifying and following the natural cleavage lines of the stone. Splitting or rough dressing yields a number of different stone products: rough-hewn rubble, rough slabs and curbstones for exterior paving and landscaping, brick-sized blocks and wall stone, ashlars for wall facing, architectural and street furniture items (the two latter products may be machine produced or hand-dressed by expert stonemasons).

MASONRY STONE

Brick-sized Building Blocks

Brick-sized blocks, or 'cantonetti' have always been the most popular and common local stone product: since ancient times the peoples of Sardinia have used this very strong, virtually indestructible material to build load-bearing, boundary and breast walls.

Central-Northern Sardinia is dotted with beautiful churches and buildings made of granite blocks, bearing witness to the deep link between the Sardinians and their rocky island.

These brick-sized blocks are obtained from large rough blocks (ranging from 0.9 to 3 sq m in volume) that are stitch drilled and then split using plug and feathers, to obtain blocks of roughly rectangular face, entirely hand made, with all surfaces rough dressed and irregular, sharp edges.

BRICK-SIZED BLOCKS - *Sizes (cm)*

Side x side	Thickness
15 / 18 x 35 / 40	15 / 18

Chapter 1 - Sardinian Granite - *Split Face Products*

Wall Stone

Low-cost stone for wall building, roughly square or rectangular. The surface face or all faces are split. It is made in various sizes, also squared, of 18/25 cm thickness and usually running length. This material is used for retaining walls, wall facing, river embankments etc.

Buildings entirely made of granite
Split face building blocks for load bearing walls.
The other elements – jambs, lintels, pillars, capitals, balusters, thresholds, copings, balconies and brackets – are sawn.

External Wall Facing

Split face products for wall facing enhance the design of Mediterranean-style resorts and villas with their unique appeal. Their split finish fully reveals the crystalline composition of Sardinian Granite, with its changing glittery amber reflections. When split and then dressed with various degrees of finish, Granite imparts to walls a permanent solidity and fascination that stands the test of time and changing fashions. In the renowned luxury villas of Costa Smeralda, where Sardinian Granite is the prime architectural material, the endless applications

Chapter 1 - Sardinian Granite - *Split Face Products*

Wall facing

Residential complex faced with Yellow Granite units of 12/16 cm thickness, sizes 40x20 and 40x30 cm.

Surfaces are split-faced while edges are sawn to achieve easy and accurate jointing during installation.

of rough-dressed stone are shown to full advantage, beautifully blending with the pristine natural environment of the Gallura district.

Wall Ashlars

Ashlars for exterior wall facing are produced in different sizes, rectangular or square. They can be supplied with all surfaces split-faced, alternatively only the external surface is split-faced and the others are sawn. Minimum thickness is 10/12 cm and the diagonal is greater by 15 cm. Sizes and finishes can be provided according to specifications. Standard sizes are 40x30 cm and 40x20 cm.

Split face wall facing

Below:
Detail of wall with bracketed coping


1

Photos 1 and 2

The arch springer is a single shaped block, making the arcade lighter and more elegant.

Split facing stone

Wall faced in split units of 10/15 cm sizes. The window is framed by split ashlars of various sizes (thickness 20 - 35 cm).

Opposite:

Pillar

All surfaces are split-faced, edges are smoothed.

The pillar head has a slot where the wooden beam rests.

Skirting in split face units

Antique finished split face units, bordered by a thin coping. The pillar is faced with wall stone of different sizes.

Split Face Blocks

These stone units (*basoli*) have warm gray, yellow and brown colors. An antique finish is also available. They are of square or rectangular shape, all surfaces are split-faced.


2

Split face units

Below:

External skirting course with antique-finished split stone.

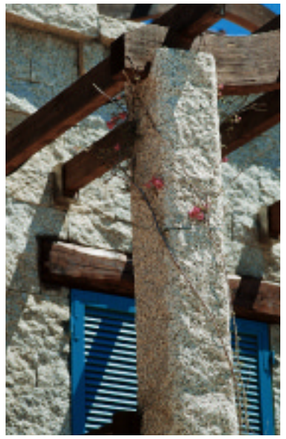
Below, left:

detail of split face units without antique finish.

Basoli are used especially for wall facings, but also have several landscaping applications: they may be used to pave courtyards, footpaths in green areas, parking areas etc.

Split face units - *Sizes (cm)*

Side x side	Thickness
9 / 11 x 14 / 16	5 / 8
15 / 18 x15 / 18	5 / 8
15 / 18 x 35 / 40	9 / 12



External Paving

Granite Cubes

Small granite cubes are used to pave any type of external surface, in residential and urban areas, both walkways and driveways. Cubes are obtained from coarse slabs that are split by the metal points of special cubing equipment, obtaining roughly cubic units of the same thickness as the original slabs, split-faced on all sides.

A number of historic city centers have regained their ancient splendor thanks to cube paving, which enhances the natural aspect of the rock. Granite cubes are also produced in the tumbled type, with antique-finished surfaces and smoothed edges. Sardinian Granite cubes, in different colors and finishes (plain or tumbled), make elegant, colorful walkways and pavements, a true pleasure both for the eye and to walk on.

Cubes - Standard sizes (cm)

Thickness or height	*Use (type of surface)*
Type 4/6	pedestrian surfaces
Type 6/8	medium wheeled traffic
Type 8/10	heavy wheeled traffic

SPLIT FACE AND ANTIQUE FINISH CUBES - *Sizes (cm)*			
Height/thickness	4 ÷ 6	6 ÷ 8	8 ÷ 10
Side	4 ÷ 6	6 ÷ 8	8 ÷ 10
Weight (kg/m^2)	100	130	170
No. of units/m^2*	~ 380	~ 200	~ 120
Face:	split		
Sides:	split		
Back:	split		

Cubes in 10/12,12/14 and 14/20 cm sizes are also supplied on request.
**With standard joints and segmental arch pattern*

Chapter 1 - Sardinian Granite - *Split Face Products*

Cubes

Split face paving cubes of variable sizes and finish: standard, with sharp edges and rough surface, and tumbled, with smoothed edges and antique finish, smoothed surface.

Sidewalk

6/8 cubes in combination with antique-finished 4/6 cubes.

Restoration of an old square

The recently installed paving consists of 8/10 cubes alternating with slabs of flamed granite converging towards the center of the square in a precise, appealing geometric pattern. The church, also shown on page 50, is entirely built in granite blocks.

Chapter 1 - Sardinian Granite - *Split Face Products*

Cube paving

6/8 cubes, stone types 'Gray Granite' and Basalt Andesite, installed with 'Florentine' pattern, a design often used for large pedestrian surfaces. The smaller cubes are placed at the foot of the arches, while the larger ones are placed at the centre (crown). This ensures that dimensional tolerances are used to the best advantage.

Restoration projects

Split face cube pavings are ideal for the narrow and winding alleyways of historical centers, thanks to the flexibility of this paving system and to the evocative power of natural stone.

Large steps

The wide steps are paved with cubes and flamed granite slab inserts; curbstones have sawn surfaces and smoothed upper edges.

Below, left:

Split face curbstones

Curbstones

Curbstones are rectangular in shape, either split-faced or sawn. They are usually supplied in running lengths but on request also in fixed lengths. Minimum thickness is 15 cm. They form straight or curved lines. They are used to border flowerbeds, sidewalks and paved areas. If the area bordered by the curb is paved with thick stone elements, the thickness of the curb's hidden side can be gauged so as to avoid the wide joint lines that would be required when linking the curb to the paving stones. The lower part of curbstones can be hollowed with a milling machine to make rainwater catchment drains.

RUNNING LENGTH CURBSTONES - *Sizes (cm)*

Length	Thickness
40 / 60	15 - 18

Cobblestones

Granite cobblestones bring back the fascination of the cobblestone and mosaic floors of ancient patrician villas. They are obtained from granite fragments of different colors (Grey and Yellow Granite), smoothed and polished in the rock tumbler. They are available in various sizes (of roughly square or rectangular shape) and are used mainly to pave pedestrian areas (if used to pave streets and driveways, bands of stone slabs must be put in place to channel vehicle traffic. When installed 'upright' (longer axis up), cobblestones can better withstand the moderate pressure of occasional vehicles. For pedestrian areas, they can be set on their flat side or on their narrow side (edge-set). The latter arrangement is shown in the photo on this page. They can be combined with other stone units (slabs, small cubes, split face blocks), to achieve an endless variety of beautiful paving designs. They are easy to install and arrange, provide a level walking surface, and have excellent durability. Diagonal length ranges from 5 to 18 cm. To pave 1 sq m of surface about 100 kg of cobblestone are required.

Architectural Features and Details

Chimney cowl

Faces are coarse finished; sawn backs, sides and feet.

North-Eastern coast

The outline of the Tavolara isle makes a stunning view from the lavish beach houses shown on these and the following pages.

Industrial Fabrication

A wide range of architectural features and details can be obtained by splitting and hewing, starting from a rough block: pillars, capitals, balustrades, balcony tops, jambs, lintels, brackets, sills and steps, as shown on the previous pages.

Hand-Worked Granite

Craftwork fabrication, i.e. hand-working of stone articles, enhances the natural qualities of granite. To create these unique pieces, master stonemasons first split from the cubic stone unit a volume of stone of the desired size and then shape it by mallet and chisel, first using a large half-point, then a fine half-point, and finally manual bushhammering – or fine picking – all the time carefully calibrating the power of each strike to avoid any damage. The bushhammer is a mallet with a square head carrying on the tip a replaceable plate with a varying number of metal points (from 25 to 81) according to the desired fineness and precision of the finishing process. Another delicate and painstaking operation (in Italian known as *agugiatura*, from the Ligurian dialect word for needle, *agugia*) is carving out hollows and grooves, or finishing edges. To obtain a smooth, even surface, the stone mason can then proceed to fine picking by means of a toothed chisel, making uniform grooves on the stone. Thus originally shaped pilasters, capitals, jambs, lintels, cornices, fireplaces and steps can be molded, as well as any other element required by the designer for external or internal applications. In order to follow the designer's specification, the stonemason must receive a full-size plywood template of the requested item. Each hand-made and finished stone item is a one-of-a-kind creation, whose value increases over time and which looks and feels far more natural and appealing than industrial stone articles.

Chapter 1 - Sardinian Granite - *Split Face Products*

Garden pathways

Large slabs with dressed face. Edges and back are split.

External wall facings

Ashlars frame the windows and line the corners of the walls to the top.

They have rough-pointed visible surfaces and sawn joints, while remaining surfaces are split-faced. The walls are faced with irregular stones.

Bracket

Size 60x30x20 cm, dressed faces and split back.

Lintel

It consists of a single piece, hand-dressed from a cubic stone.

Colonnade

Pillars (30x30x200 cm) and capitals (40x40x30cm) with point-finished surfaces and chamfered edges. The lower surface of the capitals is sawn.

Above and opposite:

Window

Ashlar framing, with hammer-dressed faces and sawn joints. Sizes of ashlars may vary depending on project specs. In this case, they are 30x20x12 cm.

The sill (100x40x14 cm) is hammer dressed on the face and upper edge; the remaining surfaces are split-faced.

Arch

Ashlars with hammer-dressed face, sawn joints and split face hidden surfaces. The abutments are lined with rough-dressed faces while joints and backs are split-faced and sawn.

The arch is surrounded by wall stone with split surfaces.

The photos on these pages show the beauty and range of architectural elements obtained from the hand working of Granite, starting from split face stone which is then dressed with mallet and chisel or fine picked. Edges can be smoothed or chamfered as required. Hand-dressed stone typically has a slightly uneven surface. This is indeed the hallmark of this type of production, since no two blows of the mallet are exactly the same.

The craft of the local stonemasons was well known also to Costa Smeralda developers. As the story goes, when the exclusive Porto Cervo resort was being built, the local stone dressers were asked by the Aga Khan Karim himself not to be too precise; he wanted the stone surface to resemble as closely as possible the natural appearance of the rock, so that the hand of man would be barely noticeable.

The arch of the entryway is made of split face ashlars. The faces are rough-punched, while backs and sides are sawn.

The wall is clad in 'country stones'. Ashlars can be supplied in any shape and size. Standard craft production is in square and rectangular sizes, with thickness not less than 10/12 cm.

**The mallet weighs about 1 kg. The handle (as for the bushhammer) is made of olive or lemon wood, chosen because of their durability and because they retain a degree of elasticity, also after long use. The chiseling points have square tips or a central groove. They are 25-30 cm long. To mark the surface with broken-line grooves a chisel with up to four notches on its cutting edge is used instead.*

Chapter 1 - Sardinian Granite - *Split Face Products*

Portico

Pillars and arches of different designs provide a beautiful frame for the wide portico of this luxury villa.

The stone units composing the arch are perfectly cut.

The units for longitudinal arches are usually in uneven numbers and must be squared very carefully, so that during installation mortar thickness ranges from 5 to 15 mm.

Centering of a longitudinal arch is shown on page 215.

Shaped capital

This capital measures 45x45 cm, and is 15 cm thick.
The sides are hammer-dressed, upper and lower surfaces are sawn. The pillar (40x40x220 cm) has hammer-dressed visible faces, sawn top and bottom surfaces.

Benches

They measure 120x40x14 cm, with smoothed heads, rough-dressed faces and sawn back. The stands (30x30x14 cm) are also rough dressed.

Bollards

Rough dressed upper surface and sawn back. Size: diameter 40 cm, height 60 cm.

Detail of a small capital

Placed between a masonry column and a wooden truss, fine dressed.

Granite Granulate

Granite granulate is most often used as an aggregate for mortar or grout. It is obtained by crushing fragments from granite processing or from rock quarried for this purpose from highly fractured deposits.
The crushing plant is located close to the quarry face: here the waste stone from the different quarry operations are conveyed. Quarry waste and fabrication trimmings usually amount to over 50% of total rock quarried (or even up to 70%). The crushing plant consists of a belt conveyor, two separate crushers and an output line (a vibrating screen with four screening levels) and process water discharge channel. The material is carried along the line by means of belt conveyors and hoppers. The stone fragments (maximum size 70 cm) are placed in the feeder by a loading shovel. From there they are transferred to the crusher (jaw breaker and simple crusher).

GRANITE GRANULATE - *Sizes (mm)*
Grit 0 / 4
Grit 4 / 8
Fine crushed aggregate 8 / 15
Fine crushed aggregate 15 / 25

SARDINIAN GRANITE
Grigio Malaga
(Malaga Gray)

Unit weight	Kg/m^3	2,668
Imbibition coefficient	%	0.0031
Thermal linear expansion coefficient	mm/m°C	7.8 E-6
Compression breaking load	N/mm^2	187.6
Compression breaking load after freeze/thaw cycles	N/mm^2	167.6
Modulus of rupture	N/mm^2	15.95
Elasticity modulus	N/mm^2	51.458
Impact resistance	J	5.76
Frictional wear	mm	2.38
Knoop Micro-hardness	N/mm^2	5.650

% Chemical composition	
SiO_2	68.7
Al_2O_3	18.0
Fe_2O_3	3.5
CaO	2.6
MgO	0.95
Na_2O	4.2
K_2O	3.2
TiO_2	0.37
P_2O_5	0.10
P.F.	0.60

Chapter 1 - Sardinian Granite

SARDINIAN GRANITE
Grigio Nuraghe
(Nuraghe Gray)

Unit weight	Kg/m^3	2,590
Imbibition coefficient	%	0.0036
Thermal linear expansion coefficient	mm/m°C	7.0 E-6
Compression breaking load	N/mm^2	194.0
Compression breaking load after freeze/thaw cycles	N/mm^2	184.8
Modulus of rupture	N/mm^2	12.66
Elasticity modulus	N/mm^2	44.875
Impact resistance	J	5.27
Frictional wear	mm	2.67
Knoop Micro-hardness	N/mm^2	6.728

% Chemical composition	
SiO_2	73.7
Al_2O_3	13.7
Fe^2O^3	2.1
CaO	1.2
MgO	0.21
Na_2O	4.3
K_2O	4.2
TiO_2	0.10
P_2O_5	0.07
P.F.	0.32

SARDINIAN GRANITE
Grigio Perla
(Pearl Gray)

Unit weight	Kg/m^3	2,615
Imbibition coefficient	%	0.0033
Thermal linear expansion coefficient	mm/m°C	7.8 E-6
Compression breaking load	N/mm^2	189.3
Compression breaking load after freeze/thaw cycles	N/mm^2	166.1
Modulus of rupture	N/mm^2	15.10
Elasticity modulus	N/mm^2	53.088
Impact resistance	J	5.15
Frictional wear	mm	2.89
Knoop Micro-hardness	N/mm^2	6.367

% Chemical composition	
SiO_2	77.5
Al_2O_3	13.1
Fe_2O_3	1.9
CaO	1.6
MgO	0.28
Na_2O	3.9
K_2O	4.5
TiO_2	0.12
P_2O_5	0.02
P.F.	0.48

Chapter 1 - Sardinian Granite

SARDINIAN GRANITE
Rosa Antico
(Antique Pink)

Unit weight	Kg/m^3	2,635
Imbibition coefficient	%	0.0035
Thermal linear expansion coefficient	mm/m°C	7.3 E-6
Compression breaking load	N/mm^2	194.5
Compression breaking load after freeze/thaw cycles	N/mm^2	169.7
Modulus of rupture	N/mm^2	13.27
Elasticity modulus	N/mm^2	53.911
Impact resistance	J	5.01
Frictional wear	mm	2.56
Knoop Micro-hardness	N/mm^2	6.213

% Chemical composition	
SiO_2	75.8
Al_2O_3	14.4
Fe_2O_3	3.0
CaO	2.4
MgO	0.70
Na_2O	4.3
K_2O	3.9
TiO_2	0.32
P_2O_5	0.09
P.F.	0.58

SARDINIAN GRANITE
Rosa Beta
(Beta Pink)

Unit weight	Kg/m^3	2,635
Imbibition coefficient	%	0.0035
Thermal linear expansion coefficient	mm/m°C	7.3 E-6
Compression breaking load	N/mm^2	194.5
Compression breaking load after freeze/thaw cycles	N/mm^2	169.7
Modulus of rupture	N/mm^2	13.27
Elasticity modulus	N/mm^2	53.911
Impact resistance	J	5.01
Frictional wear	mm	2.56
Knoop Micro-hardness	N/mm^2	6.213

% Chemical composition	
SiO_2	75.8
Al_2O_3	14.4
Fe_2O_3	3.0
CaO	2.4
MgO	0.70
Na_2O	4.3
K_2O	3.9
TiO_2	0.32
P_2O_5	0.09
P.F.	0.58

Chapter 1 - Sardinian Granite

SARDINIAN GRANITE
Rosa Cinzia
(Cinzia Pink)

Unit weight	Kg/m^3	2,612
Imbibition coefficient	%	0.0029
Thermal linear expansion coefficient	mm/m°C	7.2 E-6
Compression breaking load	N/mm^2	194.0
Compression breaking load after freeze/thaw cycles	N/mm^2	168.9
Modulus of rupture	N/mm^2	12.54
Elasticity modulus	N/mm^2	53.975
Impact resistance	J	5.27
Frictional wear	mm	2.47
Knoop Micro-hardness	N/mm^2	5.511

% Chemical composition	
SiO_2	74.0
Al_2O_3	13.6
Fe_2O_3	1.9
CaO	1.5
MgO	0.27
Na_2O	3.7
K_2O	4.7
TiO_2	0.13
P_2O_5	0.04
P.F.	0.34

SARDINIAN GRANITE
Rosa Nule
(Nule Pink)

Unit weight	Kg/m^3	2,600
Imbibition coefficient	%	0.0035
Thermal linear expansion coefficient	mm/m°C	7.3 E-6
Compression breaking load	N/mm^2	192.0
Compression breaking load after freeze/thaw cycles	N/mm^2	175.1
Modulus of rupture	N/mm^2	11.11
Elasticity modulus	N/mm^2	47.989
Impact resistance	J	5.34
Frictional wear	mm	2.61
Knoop Micro-hardness	N/mm^2	5.995

% Chemical composition	
SiO_2	77.3
Al_2O_3	13.2
Fe_2O_3	3.0
CaO	2.4
MgO	0.70
Na_2O	4.3
K_2O	3.9
TiO_2	0.32
P_2O_5	0.09
P.F.	0.46

Chapter 1 - Sardinian Granite

SARDINIAN GRANITE
Ghiandone Gallura

In 'Ghiandone Sardo' Granite types, individual K-feldspar crystals have the shape and size of an acorn. It is interesting to note that the crystals of this granite are often arranged on well-defined bedding planes, produced by the forces which acted on the cooling magma.

Unit weight	Kg/m^3	2,638
Imbibition coefficient	%	0.0028
Thermal linear expansion coefficient	mm/m°C	6.5 E-6
Compression breaking load	N/mm^2	184.0
Compression breaking load after freeze/thaw cycles	N/mm^2	173.0
Modulus of rupture	N/mm^2	14.51
Elasticity modulus	N/mm^2	54.075
Impact resistance	J	4.11
Frictional wear	mm	2.65
Knoop Micro-hardness	N/mm^2	6.176

% Chemical composition	
SiO_2	74.1
Al_2O_3	15.6
Fe_2O_3	2.3
CaO	2.2
MgO	0.81
Na_2O	4.2
K_2O	4.9
TiO_2	0.23
P_2O_5	0.07
P.F.	0.77

SARDINIAN GRANITE
Ghiandone Limbara

Unit weight	Kg/m^3	2,613
Imbibition coefficient	%	0.0029
Thermal linear expansion coefficient	mm/m°C	7.2 E-6
Compression breaking load	N/mm^2	179.7
Compression breaking load after freeze/thaw cycles	N/mm^2	165.3
Modulus of rupture	N/mm^2	12.57
Elasticity modulus	N/mm^2	50.766
Impact resistance	J	4.99
Frictional wear	mm	2.76
Knoop Micro-hardness	N/mm^2	6.039

% Chemical composition	
SiO_2	78.0
Al_2O_3	12.8
Fe_2O_3	1.9
CaO	1.5
MgO	0.52
Na_2O	4.0
K_2O	5.3
TiO_2	0.18
P_2O_5	0.07
P.F.	0.57

Chapter 1 - Sardinian Granite

SARDINIAN GRANITE
Giallo San Giacomo
(San Giacomo Yellow)

Unit weight	Kg/m^3	2,622
Imbibition coefficient	%	0.0033
Thermal linear expansion coefficient	mm/m°C	8.3 E-6
Compression breaking load	N/mm^2	188.0
Compression breaking load after freeze/thaw cycles	N/mm^2	171.0
Modulus of rupture	N/mm^2	12.80
Elasticity modulus	N/mm^2	53.088
Impact resistance	J	5.0
Frictional wear	mm	0.117
Knoop Micro-hardness	N/mm^2	N.D.

SARDINIAN GRANITE
Rosa Ferula
(Ferula Pink)

Unit weight	Kg/m^3	2,630
Imbibition coefficient	%	0.0034
Thermal linear expansion coefficient	mm/m°C	6.4 E-6
Compression breaking load	N/mm^2	192.2
Compression breaking load after freeze/thaw cycles	N/mm^2	169.9
Modulus of rupture	N/mm^2	15.20
Elasticity modulus	N/mm^2	53.25
Impact resistance	J	5.15
Frictional wear	mm	0.70
Poisson's coefficient		0.23

% Chemical composition	
SiO_2	66.1
Al_2O_3	0.15
Fe_2O_3	1.04
CaO	2.4
MgO	0.05
Na_2O	4.8
MnO	0.029
K_2O	10.8
TiO_2	0.32
P_2O_5	0.43
PbO	ppm <100

Example of Supply Specifications

External Paving in Split Cubes of Sardinian Granite

Supply and installation of ***Sardinian Granite*** paving (commercial type:…), ***in cubes measuring 6/8 cm in thickness, with split face and sides.*** The paving shall be installed in ***Florentine pattern,*** on a 6 cm-thick cement mortar base course, using sand of the appropriate grain size, dry-mixed with R 325 cement in the amount of 10 kg/sq m.

Supply price shall include the following work: laying of the base course; establishment of the required gradient for rainwater drainage; soaking and compacting by means of vibrating plates of appropriate size and weight; replacement as needed of any cubes broken or chipped during laying; sealing of the joints with cement grout and sand; subsequent surface cleaning with sawdust, until the surface is perfectly cleaned, and any other operation required for a workmanlike execution.

Cost Euro/m^2 (excluding preparation of sub-base)

Extra cost for paving in Sardinian Basalt cubes

Extra cost pertaining to the supply and installation, in addition to Sardinian Granite paving cubes of 6/8 cm thickness, of supplementary materials, i.e. cubes of Sardinian Basalt, of thickness 6/8 cm, with split face, sawn sides and quarry split back.

Cost Euro/m^2

Sardinian Granite Cobblestone Paving

Supplying and installation of ***Sardinian Granite*** paving (commercial type:…) ***in square and/or rectangular cobblestones (length of diagonal 5 cm min. 18 cm max), with tumbled (antique) faces and smoothed edges.*** The paving shall be installed, according to project drawings, on a cement mortar base course of minimum thickness 8 cm, using sand of the appropriate grain size, dry-mixed with R 325 cement in the amount of 10 kg/sq m. Cobblestones will be tightly set so as to achieve an even walking surface.

Supply price shall include the following work: supply of the base course; shaping if needed of the cobblestone surface and establishment of the required gradient for rainwater drainage; soaking and compacting by means of vibrating plates; replacement as needed of any cobblestones broken or chipped during laying; sealing of the joints with cement grout and sand; subsequent surface cleaning with sawdust and/or water and any other operation required for a workmanlike execution.

Cost Euro/m^2 (excluding preparation of sub-base)

Paving in Sardinian Granite Sawn Pavers

Supplying and installation of ***Sardinian Granite*** paving (commercial type:…), ***in sawn pavers measuring 10 cm in thickness and of size (side x side) 20x30 -30x40 and 40x50 cm, with coarse bushhammered upper surface, sawn back and split face sides.***

The paving shall be installed, according to project drawings, on a 6 cm-thick cement mortar base course, in the ratio 250 kg type R 3.25 cement to 1 cu m of sand of the appropriate grain size. Supply price shall include the following work: supply of the base course; establishment of the required gradient for rainwater drainage; soaking and compacting by means of vibrating plates; replacement as needed of any paver broken or chipped during laying; sealing of the joints with cement grout and sand; subsequent surface cleaning with sawdust and/or water and any other operation required for a workmanlike execution.

No. **size 20x30x10* cm**

No. **size 30x40x10* cm**

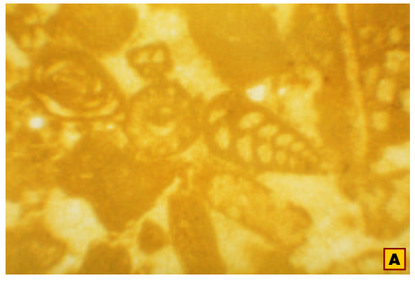
No. **size 40x50x10* cm**

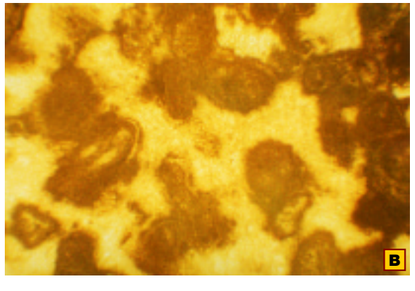
**side x side x thickness*

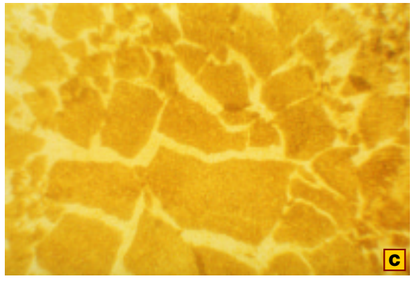
Cost Euro/m² (excluding preparation of sub-base)

OROSEI MARBLE

Geology and Stone Identification







Various types of limestone are quarried and fabricated in Sardinia, (In the province of Sassari: 'Alghero Marble' and 'Nughedu Marble'). In many areas on the island we find saccharoidal limestone, also of the Silurian Period, with black, white, cipolin and bardiglio limestones. In a number of sites across Sardinia *pietra forte* is quarried; it is a resistant, but not polishable limestone, used for masonry work. The most important stones in this category, in terms of marketing varieties, available deposits and volumes quarried, are the limestones of Orosei.

The territory of Orosei is characterized by thick strata of Mesozoic limestone and dolostone dating from the Jurassic and Cretaceous Periods, which make up the entire massif of Monte Tuttavista (805 m, extending to the North-East), where Orosei marble is quarried. The carbonatic sequence has a base of brown dolostone alternating with layers of sandy limestones, followed by strata of clear limestones, including hazelnut-colored strata.

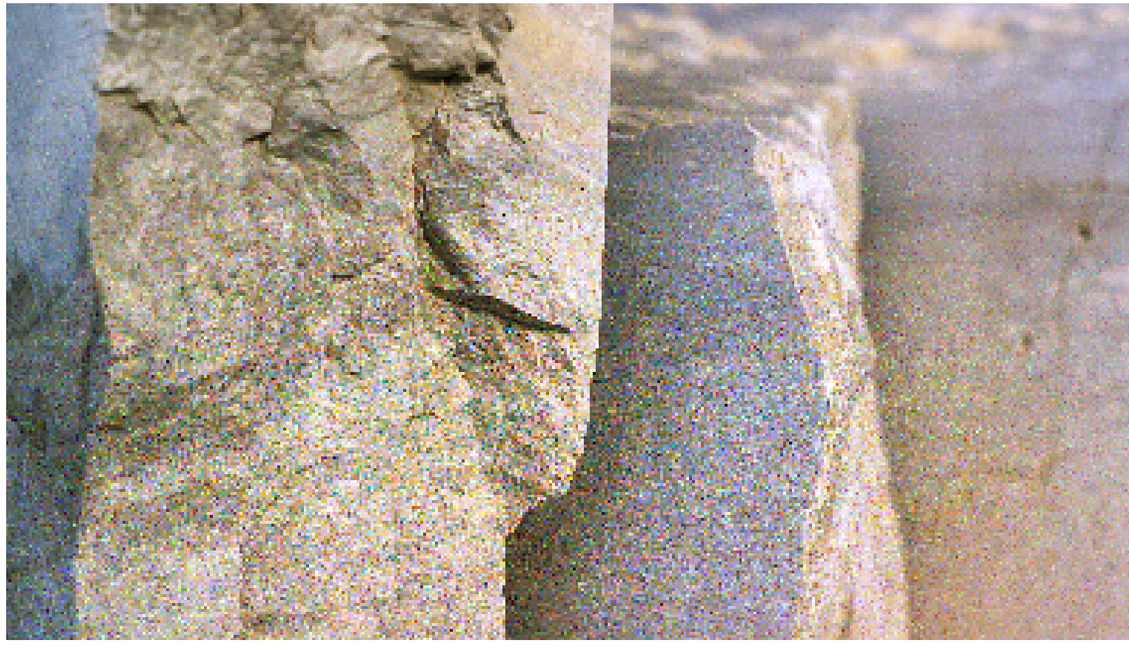
When thin slices of the rock are examined under a polarized light microscope, they are revealed as all consisting of microcrystalline calcite. Clear-colored Marble (A and B) is made up of micrite (cripto and microcrystalline calcite) with interclasts (autochthonous fragments from limestones formed in the same basin, weathered by the surf) and bioclasts, also of micrite, with microcrystalline calcite veins that filled and cemented tectonic fractures, improving the material's mechanical characteristics.

Medium-veined Marble (C) consists of granular bioclasts, formed by foraminifers, fossil and algae fragments and microcrystalline calcite interclasts set in a mosaic of partially re-crystallized calcitic micrite.

Previous page:

In Sardinia, a number of churches were erected in the early centuries of the second millennium, using large squared ashlars of white limestone, often in alternating courses with basalt ashlars, as in the beautiful church that opens this chapter: the Cathedral of S.S. Trinità of Saccargia (Codrongianus - SS), a 12th century Pisan Romanesque construction. The bell tower, adorned with two and three-light mullioned windows, is almost 40 m high.

Historical Background



Orosei Marble thicknesses, with sawn face and split sides.

Marble was the material of choice for the monuments of antiquity. The ancient chronicles* celebrate the magnificence of the marbles of the Parthenon and the Coliseum, of the temples of Babylon and Magna Graecia. Indeed, way back in 2780 BC, the first architect whose name has come down to us, the Egyptian Imhoteus, chose Marble as the best material to ensure the permanence of monuments. Thanks to the exceptional durability of this stone, we can still admire his genius when visiting the Pharaoh Zoser's pyramid at Saqqarah. Over thousands of years, Marble has adorned the exterior and interior of the most important buildings and houses. Like no other stone, it has been the protagonist, over the centuries, of sacred and monumental architecture, interior furnishing and the finest sculptures.

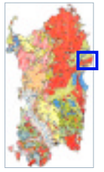
Among the earliest buildings constructed with Mesozoic limestones in Sardinia we find the Nuraghic village whose ruins are cradled in a sinkhole on a hilltop at Tiscali.

**"With wise and thoughtful decision, our ancestors decided to hand down to future generations (...) their knowledge so as to save it from oblivion."*
(Vitruvius - De Architectura - *Book VII)*

Clear Orosei Marble
These thicknesses were used to make the steps of the stairway shown on page 89.

Orosei Marble

The blue box on the map shows the Orosei Marble quarrying district.



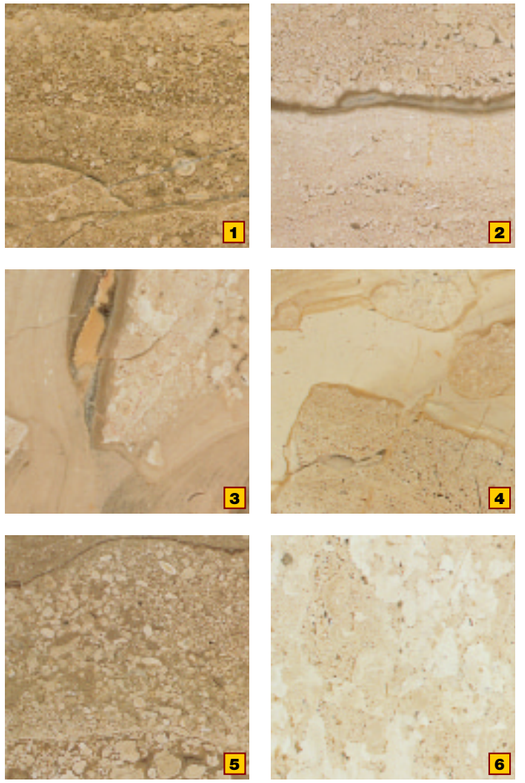
The area where Orosei marble is quarried and worked has been classified by the Italian government as one of the four industrial districts of Sardinia, and is recognized by the Regional Government as one of the four dimension stone mining districts on the island; three of them produce Granite, while the Orosei district (in Central-Eastern Sardinia), produces Marble.

The Mesozoic limestones, comprising a number of commercial marble types such as Clear, Veined and Cloudy, each with a variety of colors and veining are indeed very widespread in the territory of Orosei. The marble quarries and most fabrication plants are located over a large foothill area of about 200 hectares, while about 4-5 km inland from the coast we find large deposits of various types of Granite, the most valued of which is the pink pegmatitic, marketed under the name of Pink Ferula Granite. Quarrying and fabrication on an industrial scale began in the 1960s, and have increased steadily over the following decades, becoming the prime production sector of Central-Eastern Sardinia. Currently, a number of marble producers and fabricators operate in Orosei (16 quarries, total annual production about 80,000 cu m). These companies also manage four crushing plants that produce granulate from quarry waste and fabrication trimmings, employing about 400 skilled workers in total.

The marble industry of Orosei is well established on the domestic and international natural stone markets. The product has excellent physical and mechanical properties. The colors of the main commercial types have been much appreciated by buyers for a number of years now. The whole sector is growing steadily, thanks to the foresight and commitment of local companies, which aim at promoting local stone varieties and ensure that production meets stringent quality and price standards.

Orosei Marble - Commercial Types
In order to clearly identify the various commercial types of Orosei Marble, the following designations have been officially recognized:

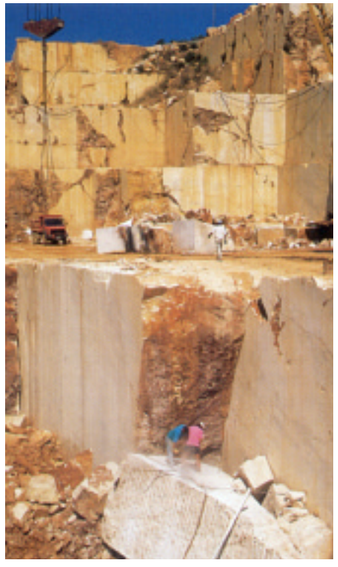
1. **Dark Veined Orosei Marble**
   Marmo Orosei Venato Scuro
2. **Medium Veined Orosei Marble**
   Marmo Orosei Venato Medio
3. **Dark Cloudy Orosei Marble**
   Marmo Orosei Nuvolato Scuro
4. **Medium Cloudy Orosei Marble**
   Marmo Orosei Nuvolato Medio
5. **Pearly Orosei Marble**
   Marmo Orosei Perlato
6. **Clear Orosei Marble**
   Marmo Orosei Chiaro



Quarrying operations
Squaring of the primary blocks.

Quarrying

Having abandoned the use of explosives, modern quarrying methods adopt advanced systems, with wire saws for vertical cutting and block selection, and chainsaws for horizontal cutting. Tripod cranes, in common use until not many years ago for hoisting quarry blocks, have been replaced by powerful load shovels and front-end loaders. All quarries are equipped with modern machinery and equipment for cutting and squaring the blocks (diamond wire saws, large chain cutters with widia cutting edges, track-mounted cutters with double pneumatic drill, hydraulic jacks and inflatable bags, fixed block cross-cutters, with diamond wire or single diamond blade). For handling and transporting the blocks within the quarry, powerful loading shovels, front-end loaders and dumpers, as well as derricks of over 30 tons carrying capacity are used.



Marble fabrication mills are equipped with high productivity machinery: multiblade diamond-studded gangsaws for sawing and diamond-blade block cutters for producing Modulmarble and Zoccolino; resin-coating equipment, various types of milling cutters; water-jet equipment for finishing and special fabrications. Outside the mill, the blocks are hoisted by means of a bridge crane of 30-40 tons carrying capacity, and are then transferred with electric trucks and/or transfer table. Handling of sawn elements inside the fabrication plant is done with automatic extractors, electric trolleys on tracks, lift trucks and bridge cranes.

All plants have at a minimum a closed-cycle system for the recovery and re-use of process water.

Chapter 2 - Orosei Marble

Quarrying phases
Loaf toppling

ROUGH BLOCKS - *Sizes (cm)*	
1st grade rough blocks	
Height	150 - 170
Length	250 - 310
Width	150 - 180

Price per cu m may vary depending on the quarry face and block cutting characteristics.

2nd and 3rd grade rough blocks

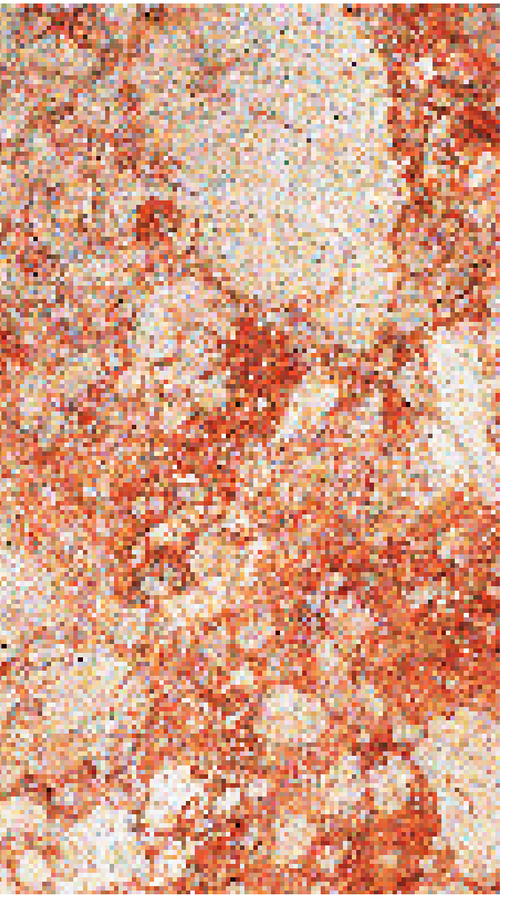
Size (height, length and width) may be the same as 1st grade blocks.
They may have color inconsistencies and/or textural defects.

Price per cu m may vary depending on block cutting characteristics.

SLABS - *Sizes (cm)*	
Thickness	min.1.6 / max 10
Length	may vary according to block size
Width	may vary according to block size
Surfaces	sawn – honed – polished – bushhammered – sanded – acid-washed

STRIPS - *Sizes (cm)*	
Thickness	1.6 - 2 - 3
Length	min. 120
Width	min. 2 / max 40
Surfaces	sawn – honed – polished – bushhammered – sanded – acid-washed

Orosei stone types
High-quality breccia quarried in the Orosei district (Zanzi Quarry)



Surface Finishes

The main types of surface finishes of Marble products are honed, polished, bushhammered, flamed, sandblasted, acid washed and stuccoed.

A polished finish is usually applied to internal flooring and wall facing elements, while sandblasting or bushhammering are more common for exterior paving and wall cladding.

Some kinds of finish are specific for Marble. For instance, the fine punched finish, which achieves an extra-fine texture can be applied only to marble and other soft rocks, whereas it is not suitable for harder siliceous rocks, such as Granite.

The table on page 101 lists mean values, obtained by taking the average of the three varieties of Orosei Marble, and the mean values of the same properties recorded for similar types of marble from Tuscany (the latter values are taken from the book *I Marmi Apuani*, edited by ERTAG for the Region of Tuscany).

Mean uniaxial compressive strength of Orosei Marble types is decidedly higher than that of their Tuscan counterparts, while flexural strength is slightly lower, but still satisfactory.

A regards impact resistance, tests were carried out on samples taken from the most common commercial sizes, whose thickness is usually 15-17 mm for floor tiles and 20-30 mm for stair and wall facings.

On the other hand, similar tests on Tuscan marble types were run on samples of 50 mm thickness. In the light of the different thicknesses, impact resistance of Orosei Marble is clearly superior to that of Tuscan Marble.

Orosei Marble also has greater abrasion strength, and excellent resistance to sand abrasion.

(continues on page 101)

OROSEI MARBLE

External Wall Facing

External Paving and Finishings

Flooring

Architectural Details

Street Furniture

Facings

Orosei Marble produces exceptional functional and aesthetic results when used to clad large structures. Thanks to its excellent physical and mechanical properties, it can be cut into large, extra thin panels (resin-coated and/or screened), cut to size according to designer specs and suitable for any type of cladding, such as frame cladding with airspace (the same remarks made in the boxes on pages 28 and 32 apply). The panels are perfectly cut to size, for ease of installation and meet all types of anchoring requirements. For purposes of static calculation of the material used, it is necessary to consider the technical values of the chosen stone type, the geo-climatic characteristics of the site where it is to be installed, and the structural specs of the building. Table A shows the technical characteristics to be assessed, based on a number of fundamental reference parameters.

Table A

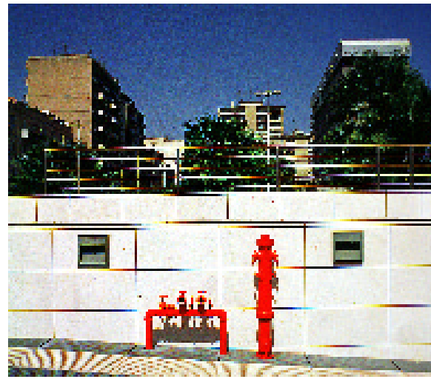
Wind Action	Bending – Elasticity modulus
Temperature Range	Thermal expansion – Frost resistance
Structural Load	Unit weight
Anchoring systems	Bending – Impact resistance – Micro-hardness
Moisture/Frost	Imbibition – Frost resistance
Seismic Risk	Compressive strength – Bending
	Modulus of elasticity
Air Pollution	Resistance to acids and oxidizers.

Orosei Marble Quarry Yield and Reserves

Surface stone reserves, reaching in some points a thickness of 600 m, are about 34 million sq m; estimated total reserves exceed 62 million cu m, but may even exceed 300 million cu m. The stone quarried in about 30 years of activity is just 6% of current surface reserves. Exploitable reserves cover a surface area of over 80 hectares. Of these, just 33 are currently being exploited under quarrying licenses. At year end 1998, total quarrying capacity was about 80,000 cu m/year. Sawing ratio (800,000 sq m/year for slabs and about 1,600,000 sq m/year for strips) was about 75% of quarried material. Finishing, polishing and resin-coating capacity is about 40% of sawn material.

To ensure their durability, artistic and architectural works in marble are treated with water-resistant products – most commonly fluorine polymers. Indeed, water is the main weathering agent, as it triggers chemical, physical and biological deterioration of the stone.

These protective products must be colorless, stable under heat, radiation and chemical agents, they must not react chemically with the stone and must maintain permeability to water, vapor and gases.



Some major cladding and/or paving projects with Orosei Marble

Paris - C. De Gaulle Airport
Paris - New Subway
Paris - Lafayette Department Stores
Santo Domingo - Airport
Singapore - Golf Club
Saragozza - Shopping Malls
Cagliari - Credito Industriale Sardo

They have a minimum thickness of 1.7 cm and are available in square and rectangular shapes, with minimum standard sizes of 15x15 and 10x20 cm respectively.

LARGE CLADDING TILES - *Sizes (cm)*

Side x side	Min. thickness
30 x 30	2
30 x 60	2
40 x 40	2
40 x 60	2
30 x 30	3
30 x 60	3
40 x 40	3
40 x 60	3
40 x 80	3

All intermediate sizes available, of square or rectangular shape. For rectangular tiles, maximum length of the shorter side is 40 cm, of the longer side 80 cm. Thickness may vary to order, minimum thickness 2 cm (or less on request). Maximum tolerances ± 0.5 mm. Surface finish: to order.

Packaging: in sealed cartons with the slabs laid on sheets of polystyrene. Transport on trailer truck: on 40 sq m wooden pallet, complete with shrink wrapping. Transport by container: 30 sq m crates.

External Paving and Finishings

Sawn pavers

These are square or rectangular elements, of 2 cm minimum thickness and with sawn sides. The length of rectangular pavers, usually double their width, may be running or defined according to standard measures.
Sawn pavers can also be supplied in custom shapes and sizes. Common finishes on the visible surface of paving stone are bushhammering and sandblasting.
Small marble cubes are also produced in different finishes, including tumbled.

SLABS *- Sizes (cm)*

Side x side	Min. thickness	Weight (kg/m²)
Min. 15 x 30	3	56
Max 80 x 80	4	85

CUBES AND ANTIQUE-FINISHED CUBES *- Sizes (cm)*

Height/thickness	4÷6	6÷8	8÷10
Side	4÷6	6÷8	8÷10
Weight (kg/m²)	100	130	170
No. of units/m²	~380	~200	~120

opposite:

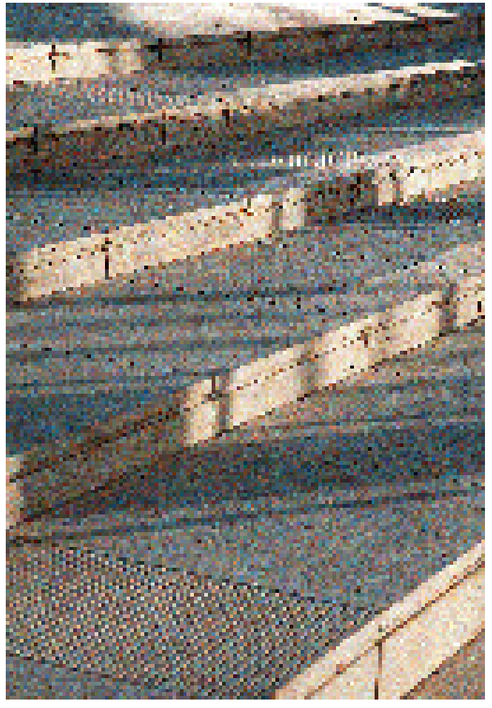
Squares

Sardinian Marble (slabs) and Basalt (antique-finished setts).

Slabs with different surface finishes, installed so that the grooved units form a guide strip offering a non-slip surface to pedestrians in all weathers.

RUNNING LENGTH CURBSTONES *- Sizes (cm)*

Length	Thickness	Weight (kg)
Running	4 / 10	110
Running	6 / 8	135
Running	8 / 10	190



Above

Square

Marble and Basalt paving.

Curbstones

Curbstones bordering the flower-beds of a square paved with fine-picked Granite slabs.

Stairway

Grooved surface guide strips are also placed in the stairway.

Stairway

The steps (square sides and chamfered edges) consist of thick units laid in running bond courses.

In the foreground: coping. Copings are produced, in running or required lengths, from slabs of 3 cm min. thickness. The copings shown here are 5 cm thick.

Copings

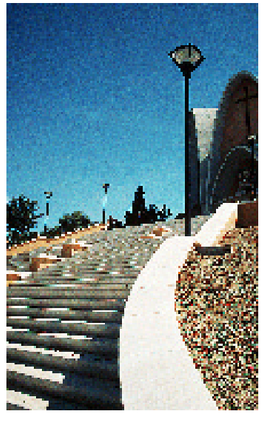
The curved, sloping balustrade, topped by white marble copings, is a distinguishing features of this landscaping project.

Supply Specifications

PAVING IN OROSEI MARBLE SLABS

Supply and installation of Orosei Marble paving (commercial type: Clear Orosei Marble), in slabs measuring 40 cm in length, 20 cm in height and 4 cm in thickness, with sanded upper surface, sawn back, square sides and sharp edges. The paving shall be installed, according to project drawings, on a 6 cm-thick cement mortar base course, in the ratio of 250 kg of type R 3.25 cement to 1 cu m of sand of the appropriate grain size.
Supply price shall include the following work: supply and laying of the base course with a surface cement coating – not less than 6 kg/sq m; establishment of the required gradient for rainwater drainage; vibration; replacement as needed of any slabs broken or chipped during laying; sealing of the joints with cement grout and sand; subsequent surface cleaning with sawdust, cutting, trimming and any other operation required for a workmanlike execution.
- Supply of the sub-base not included.

Cost Euro/m^2



Flooring

Small Orosei Marble units, together with Basalt and trachyte units (all of 2 cm thickness), were custom-made for this elegant mosaic floor.

These small units can be arranged in endless designs and color patterns. The skirting (thickness 2 cm) has a chamfered edge.

Flooring

Orosei Marble offers an almost endless variety of flooring solutions, thanks to the wide range of commercial types available and the large number of standard products, available in sizes from 3 x 3 cm tiles to Modulmarble and large tiles. Tiles of different color and veining pattern can be combined, creating elegant floors with striking color effects. Polished marble floors can be re-polished several times, using diamond-tipped pads.
This system does not require the use of lead or chemical products, does not produce sludge, and is very effective and durable. The Marble is smoothed using progressively finer grades of diamond tipped pads, until its typical shine is restored, without any reduction in the floor's thickness.

Chapter 2 - Orosei Marble - *Finished Products*

Previous page:

Flooring

In this example, the stone was sawn so as to obtain a mottled effect, showing the beautiful veined texture and color patterns of Orosei Marble.
(By kind permission of: Nazareno Gabrielli Boutique - Cagliari).

Slab finishing

Resin-coating equipment.

Cross-cutting and trimming of resin-coated slabs.

Modulmarble

Automated production line.

Production plant

Tile pallet.

Tiles

Polished tiles, rectangular or square. Minimum thickness is 1.1 cm, minimum size 15x30 cm and maximum 80x80 cm. The sides are sawn, the edges are sharp or chamfered. They are also produced in running lengths, in standard sizes as shown in the table

TILES *- Sizes (cm)*

Side x side	Min. thickness
15 x 30	1.1
20 x 40	1.6
30 x 30	1.6
30 x 60	1.6
40 x 40	1.6
40 x 60	1.6
40 x 80	1.6
80 x 80	2

RUNNING TILES *- Sizes (cm)*

Side x side	Min. thickness
running x 30.5	1.1
running x 40.5	1.1
running x 30	1.6
running x 40	1.6

Modulmarble

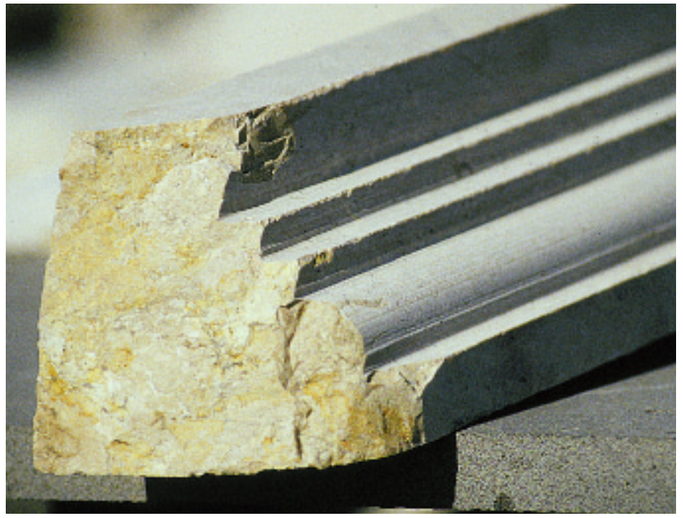
Polished tiles, of minimum size (sides)30.5x30.5 cm and thickness 1.1 cm. They are gauged, with chamfered edges.

MODULMARBLE *- Sizes (cm)*

Side x side	thickness
30.5 x 30.5	1.1
40.5 x 40.5	1.1
61.0 x 30.5	1.1

Architectural Details
Artistic Craftwork
Street Furniture

Architectural details in Orosei Marble (columns, capitals, cornices, lintels etc.) nowadays have mostly religious and funerary applications, which are not covered by this guide.
Just browsing through the pages of any Art History book we can see at a glance that, over thousands of years, marble has been used to create some of the greatest monuments of humanity.
Marble is also used to make street furniture (bollards, planters, bases, benches, etc.), in endless shapes, sizes and finishes, according to the designer's specifications.



Wall facing

Detail of chamfered edges.

The capitals and keystone are in basalt.

Sculpting in Orosei

In order to promote awareness of the characteristics and uses of local stone, the Marble and Granite Consortium and the Orosei Town Council host international events with artists from all over the world. The photos show some of the imposing sculptures created during these stone art happenings.

Artistic craftwork

Inlaid panel for cladding and flooring applications

Photo by: Salvatore Mocenni

The physical, chemical and mechanical properties of the different types of Orosei Marble listed in the technical sheets were measured by the Materials and Testing Laboratory – Institute of Construction Science – Cagliari University.

Physical and Mechanical Properties of Orosei Marbles (mean values) and of Apuan Marbles*

		APUAN MARBLES		OROSEI MARBLES
		WHITE	VEINED	
Breaking load (under uni-axial compression)				
- on dry test piece	**kg/cm²**	1,332	1,286	1,679 ± 271
- after freeze/thaw cycles	**kg/cm²**	1,282	1,237	1,527 ± 285
Flexural strength:				
- on dry test piece	**kg/cm²**	185	183	150 ± 39
Impact resistance (height of fall)				
- 30 mm thick test piece	**cm**	n.a.	n.a.	30
- 50 mm thick test piece	**cm**	57.80	53.41	n.a.
Frictional wear	**mm**	5.27	5.80	4.11 ± 0.65
Linear elasticity modulus (static)	**kg/cm²**	713,687	642,090	778,254 ± 77,930
Imbibition coefficient	**‰**	1.31	1.49	5.13 ± 2.47
Weight per unit volume	**kg/m³**	2,692	2,690	2,685 ± 41

* *Source:* Guida tecnica per l'impiego razionale del Marmo *(Industria italiana del Marmo -1992).*

Continued from page 88

The modulus of linear elasticity is also slightly higher for Sardinian marble, as a result of its greater compactness.
The mean value of the imbibition coefficient is higher for Orosei Marble, but uniaxial compression and flexural strength tests, after 20 freeze/thaw cycles, have shown this stone to be entirely frost-proof.

Limestone Granulate

Marble quarry waste and fabrication trimmings are transformed into granulate by crushing plants located near the quarries. The granulate thus obtained is used as aggregate for mortar and bitumen production, to make lime and cement and for several other specialist applications: to help reduce soil acidity in farming; in paper, paint and polypropylene production; in the production of soda; as flux for blast furnaces; to neutralize industrial acid waste and to waterproof landfills, thanks to its property of absorbing heavy metals.
Orosei limestone gravel comes in various grain sizes. Its physical, chemical and mechanical properties match those of the rock it derives from.

OROSEI MARBLE
Perlato
(Pearly)

Breaking load (under uni-axial compression):		
On dry test piece	1,664 ± 285	kg/cm²
On wet test piece	1,620 ± 271	kg/cm²
After freeze/thaw cycles	1,706 ± 209	kg/cm²
Flexural strength:		
On dry test piece	168 ± 52	kg/cm²
On wet test piece	142 ± 31	kg/cm²
After freeze/thaw cycles	154 ± 25	kg/cm²
Impact resistance: 15 mm thick test piece	13 ± 3	cm
Frictional wear	4.50 ± 0.82	mm
Sand abrasion test	0.10 ± 0.01	g
Linear elasticity modulus (static)	712,150 ± 73,410	kg/cm²
Linear elasticity modulus (dynamic)	626,000 ± 19,300	kg/cm²
Coefficient of linear thermal expansion	0.0025	mm/m°C
Imbibition coefficient	0.835 ± 0.042	%
Unit weight	2.63 ± 0.35	g/cm³
Absolute specific gravity	2.7	g/cm³
Poisson's coefficient	0.26 ± 0.02	

% Chemical composition		
$CaCO_3$	97.11	weight %
$MgCO_3$	0.75	weight %
SiO_2	0.19	weight %
TiO_2	<10	ppm
LiO_2	6	ppm
Na_2O	31	ppm
K_2O	15	ppm
Fe_2O_3	120	ppm
Al_2O_3	92	ppm
Cr_2O_3	18	ppm
CuO	11	ppm
PbO	76	ppm
MnO	27	ppm

OROSEI MARBLE
Chiaro
(Clear)

Breaking load (under uni-axial compression):		
On dry test piece	1,664 ± 285	kg/cm²
On wet test piece	1,620 ± 271	kg/cm²
After freeze/thaw cycles	1,706 ± 209	kg/cm²
Flexural strength:		
On dry test piece	168 ± 52	kg/cm²
On wet test piece	142 ± 31	kg/cm²
After freeze/thaw cycles	154 ± 209	kg/cm²
Impact resistance: 15 mm thick test piece	13 ± 3	cm
Frictional wear	4.50 ± 0.82	mm
Sand abrasion test	0.10 ± 0.01	g
Linear elasticity modulus (static)	712,150 ± 73,410	kg/cm²
Linear elasticity modulus (dynamic)	626,000 ± 19,300	kg/cm²
Coefficient of linear thermal expansion	0.0025	mm/m°C
Imbibition coefficient	0.835 ± 0.042	%
Unit weight	2.63 ± 0.35	g/cm³
Absolute specific gravity	2.7	g/cm³
Poisson's coefficient	0.26 ± 0.02	

% Chemical composition		
$CaCO_3$	97.11	weight %
$MgCO_3$	0.75	weight %
SiO_2	0.19	weight %
TiO_2	<10	ppm
LiO_2	6	ppm
Na_2O	31	ppm
K_2O	15	ppm
Fe_2O_3	120	ppm
Al_2O_3	92	ppm
Cr_2O_3	18	ppm
CuO	11	ppm
PbO	76	ppm
MnO	27	ppm

Chapter 2 - Orosei Marble

OROSEI MARBLE
Venato Scuro
(Dark Veined)

Breaking load (under uni-axial compression):		
On dry test piece	1,669 ± 238	kg/cm²
On wet test piece	1,451 ± 217	kg/cm²
After freeze/thaw cycles	1,557 ± 279	kg/cm²
Flexural strength:		
On dry test piece	147 ± 33	kg/cm²
On wet test piece	141 ± 26	kg/cm²
After freeze/thaw cycles	144 ± 279	kg/cm²
Impact resistance: 15 mm thick test piece	20 ± 6	cm
Frictional wear	4.48 ± 1.07	mm
Sand abrasion test	0.09 ± 0.01	g
Linear elasticity modulus (static)	821,120 ± 52,950	kg/cm²
Linear elasticity modulus (dynamic)	720,000 ± 24,400	kg/cm²
Coefficient of linear thermal expansion	0.003	mm/m°C
Imbibition coefficient	0.324 ± 0.058	%
Unit weight	2.66 ± 0.14	g/cm³
Absolute specific gravity	2.71	g/cm³
Poisson's coefficient	0.28 ± 0.03	

% Chemical composition		
$CaCO_3$	97.95	weight %
$MgCO_3$	0.87	weight %
SiO_2	0.2	weight %
TiO_2	<10	ppm
LiO_2	6	ppm
Na_2O	42	ppm
K_2O	15	ppm
Fe_2O_3	135	ppm
Al_2O_3	115	ppm
Cr_2O_3	19	ppm
CuO	13	ppm
PbO	82	ppm
MnO	32	ppm

OROSEI MARBLE
Venato Medio
(Medium Veined)

Breaking load (under uni-axial compression):		
On dry test piece	1,713 ± 279	kg/cm²
On wet test piece	1,543 ± 329	kg/cm²
After freeze/thaw cycles	1,660 ± 327	kg/cm²
Flexural strength:		
On dry test piece	151 ± 41	kg/cm²
On wet test piece	123 ± 31	kg/cm²
After freeze/thaw cycles	139 ± 23	kg/cm²
Impact resistance: 15 mm thick test piece	22 ± 5	cm
Frictional wear	3.80 ± 0.17	mm
Sand abrasion test	0.07 ± 0.01	g
Linear elasticity modulus (static)	807,230 ± 43,690	kg/cm²
Linear elasticity modulus (dynamic)	712,150 ± 73,410	kg/cm²
Coefficient of linear thermal expansion	0.0032	mm/m°C
Imbibition coefficient	0.487 ± 0.229	%
Unit weight	2.72 ± 0.12	g/cm³
Absolute specific gravity	2.75	g/cm³
Poisson's coefficient	0.23 ± 0.02	

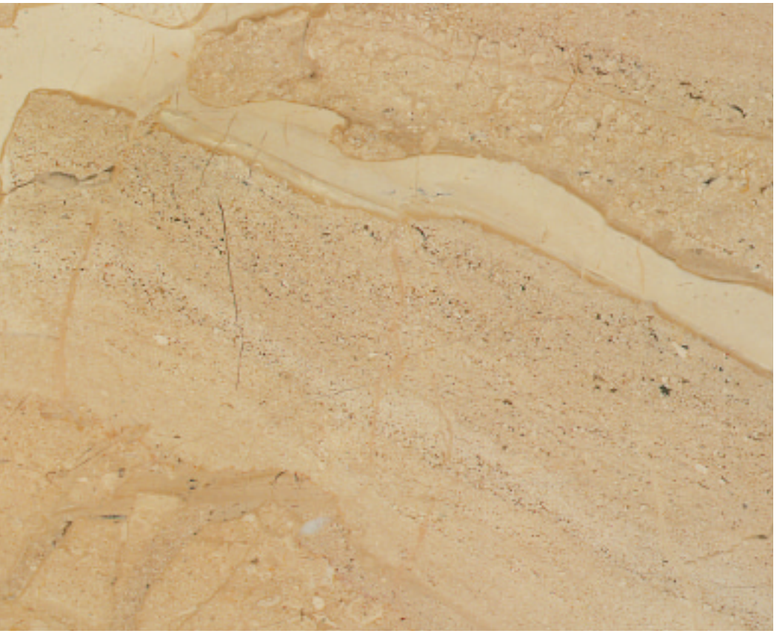
% Chemical composition		
$CaCO_3$	93.36	weight %
$MgCO_3$	0.88	weight %
SiO_2	0.15	weight %
TiO_2	<10	ppm
LiO_2	5	ppm
Na_2O	44	ppm
K_2O	17	ppm
Fe_2O_3	150	ppm
Al_2O_3	150	ppm
Cr_2O_3	19	ppm
CuO	16	ppm
PbO	78	ppm
MnO	35	ppm

Chapter 2 - Orosei Marble

OROSEI MARBLE
Nuvolato Scuro
(Dark Cloudy)

Breaking load (under uni-axial compression):		
On dry test piece	1,669 ± 238	kg/cm²
On wet test piece	1,451 ± 217	kg/cm²
After freeze/thaw cycles	1,557 ± 279	kg/cm²
Flexural strength:		
On dry test piece	147 ± 33	kg/cm²
On wet test piece	141 ± 26	kg/cm²
After freeze/thaw cycles	144 ± 10	kg/cm²
Impact resistance: 15 mm thick test piece	20 ± 6	cm
Frictional wear	4.48 ± 1.07	mm
Sand abrasion test	0.09 ± 0.01	g
Linear elasticity modulus (static)	821,120 ± 52,950	kg/cm²
Linear elasticity modulus (dynamic)	720,000 ± 24,400	kg/cm²
Coefficient of linear thermal expansion	0.003	mm/m°C
Imbibition coefficient	0.324 ± 0.058	%
Unit weight	2.66 ± 0.14	g/cm³
Absolute specific gravity	2.71	g/cm³
Poisson's coefficient	0.28 ± 0.03	

% Chemical composition		
$CaCO_3$	97.95	weight %
$MgCO_3$	0.87	weight %
SiO_2	0.2	weight %
TiO_2	<10	ppm
LiO_2	6	ppm
Na_2O	42	ppm
K_2O	15	ppm
Fe_2O_3	135	ppm
Al_2O_3	115	ppm
Cr_2O_3	19	ppm
CuO	13	ppm
PbO	82	ppm
MnO	32	ppm



OROSEI MARBLE
Nuvolato Medio
(Medium Cloudy)

Breaking load (under uni-axial compression):		
On dry test piece	1,713 ± 279	kg/cm^2
On wet test piece	1,543 ± 329	kg/cm^2
After freeze/thaw cycles	1,660 ± 327	kg/cm^2
Flexural strength:		
On dry test piece	151 ± 41	kg/cm^2
On wet test piece	123 ± 31	kg/cm^2
After freeze/thaw cycles	139 ± 23	kg/cm^2
Impact resistance: 15 mm thick test piece	22 ± 5	cm
Frictional wear	3.80 ± 0.17	mm
Sand abrasion test	0.07 ± 0.01	g
Linear elasticity modulus (static)	807,230 ± 43,690	kg/cm^2
Linear elasticity modulus (dynamic)	712,150 ± 73,410	kg/cm^2
Coefficient of linear thermal expansion	0.0032	mm/m°C
Imbibition coefficient	0.487 ± 0.229	%
Unit weight	2.72 ± 012	g/cm^3
Absolute specific gravity	2.75	g/cm^3
Poisson's coefficient	0.23 ± 0.02	

% Chemical composition		
$CaCO_3$	96.36	weight %
$MgCO_3$	0.88	weight %
SiO_2	0.15	weight %
TiO_2	<10	ppm
LiO_2	5	ppm
Na_2O	44	ppm
K_2O	17	ppm
Fe_2O_3	150	ppm
Al_2O_3	150	ppm
Cr_2O_3	19	ppm
CuO	16	ppm
PbO	78	ppm
MnO	35	ppm

SARDINIAN BASALT

The word ‘Nuraghe’ would seem to come from the Sardinian word *nurra*, meaning both heap and hollow.

Su Nuraxi 1300-1200 BC (Barumini)

This is the most imposing and best known Nuraghic site in Sardinia, dominated by the huge mass of the four-lobed central Nuraghe.

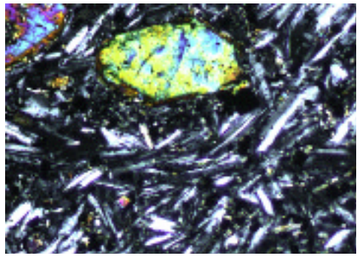
(Photo: by kind permission of the Archaeological Office for the Provinces of Cagliari and Oristano).

Nuraghic civilization takes its name from the distinctive megalithic constructions that dot Sardinia. It started in the Bronze Age (1800 - 900 BC) and lasted until the Roman conquest of Sardinia (238 BC). It knew its heyday between 1200 and 900 BC, when the Mediterranean sea was crisscrossed by sea trading routes, which also included Sardinia, well known in ancient times for its metal ores. Today, more than 7,000 Nuraghi have been identified, mostly located on bluffs and scattered across Sardinia, but more common in Central-Western Sardinia – there, in the Marghine district, their density exceeds 6 nuraghi/10 sq km.
The Nuraghi are huge megalithic towers with a round ground plan, tapering towards the top. These fortresses, which could reach considerable heights, were built with large blocks, often rough-hewn and of decreasing size in the upper courses. Construction technique was dry wall, i.e. without any mortar. The early Nuraghi had a simple layout, inspired by similar structures from the Aegean area. They consisted of a single round chamber, topped by a false dome (thòlos) ceiling. Later, more elaborate plans were adopted, with stairs, dressed ashlars and lintels, upper stories and terraces. The ruin of these imposing fortress-citadels began with the Carthaginians, who held sway in Sardinia between 510 and 238 BC and was completed in the Roman period (3rd century BC - 5th century AD). The Nuraghi, together with other megalithic structures, i.e. the Tombs of the Giants and Sacred Wells, are the most striking expression of the civic, military, funerary and religious architecture of the Nuraghic civilization and its people, the Proto-Sards.

Chapter 3 - Sardinian Basalt

Geology and Stone Identification

Basalt is an extrusive igneous rock. It is produced by interplate volcanism, in plate spreading contexts, by means of effusive eruptions with scarce explosive activity. The magma, coming from the earth’s mantle, has a very small gas content, high temperature (1100-1300 °C) and low viscosity (runny lava). The magma giving rise to basalt and andesites has the following chemical composition: silica about 50%, alumina 15%, iron oxides 10%, calcium oxides 10%. The remaining 15% comprises potassium, sodium, magnesium, titanium oxides and other lesser substances. To be classified as basalt or andesite, the rock must contain plagioclase and clinopyroxene, associated – depending on the magma’s chemical affinity – with foides, olivine and orthopyroxene or with orthopyroxene and quartz.
Basalt has a porphyritic texture, i.e. it comprises both large crystals (phenocrysts) that formed underground and have a well-defined shape, and microcrystals that formed on the surface, set in a consistent glass matrix.
Macroscopically, basalt can be vesicular, due to the presence of gas bubbles in the lava, and their subsequent degassing at atmospheric pressure, or it can be compact.
Solidified lava is called by different names depending on its appearance: Pahoehoe, A-a, Block Lavas, Pillow Lavas, Columnar Basalt. Its color, depending on its content of oxidized iron, ranges from black to red. Basalt is formed when the lava reaches the surface of the earth and flows slowly from one or more vents. This slow effusion creates large lava flows that fill surface depressions, forming flattened expanses.
Extensive areas of Sardinia have been modeled by large volumes of basalt and andesite rock. An example are the ‘Giare’, tablelands such as those of Gesturi or Nurri and other large plateaus including Campeda, in central Sardinia. Among other basalt-rich areas on the island are Montiferro, Logudoro, the Gulf of Orosei, Marmilla and the Guspinese district. Commercially exploited Sardinian Basalt was produced by extensive volcanic activity in the Pliocene and Pleistocene epochs (between 5 million and 100,000 years ago) after the opening of the Campidano plain and Tyrrhenian sea rift.



Thin section

This magnified view shows clearly the presence of two differently sized crystals (the colored ones are olivine, the black and white ones plagioclases), in a plagioclase matrix (stone sample viewed using crossed nicol prisms).

Above:
Basalt rock

Basalt columns
Guspini - Cagliari

On the other hand, most andesites in Sardinia date back to the Oligo-Miocenic volcanic cycle (between 33 and 13 million years ago). Outcrops of highly compact rock with limited fracturing can be quarried for ornamental and dimension stone purposes. Those with a high degree of fracturing are used instead for granulate production.

Historical Background

Sardinia is dotted by innumerable basalt monuments, dating back to the II-I millennium BC (chamber tombs known as *Domus de Janas*, Menhirs, Nuraghi, 'Tombs of the Giants'), bearing witness to this rock's great durability and resistance to weathering.

In the areas of the Earth where Basalt abounds, this rock has been used by man since the dawn of time, and Sardinia is no exception. Neolithic, and later, Bronze Age people, used it to build curtain walls and megalithic altars, and to make stone tools, weapons, cisterns and millstones. In the Nuraghic period (1,500-500 BC), thanks to stronger and more precise tools, Basalt became the building stone for large structures, with precise elaborate designs: the larger Nuraghi and sacred wells, with scored basalt ashlars and cyclopean lintels.

Sacred well of S. Cristina

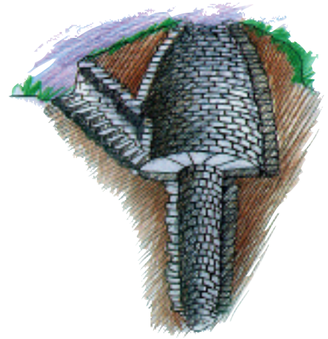
900 -700 BC (Period of Nuraghic aristocracies)

Sacred wells were associated with water cults.

The well shown in this photo is one of the largest on the island. It is made in perfectly squared and shaped basalt ashlars.

After the glories of the Nuraghic period and the magnificence of Roman mosaics (Nora, Tharros) made from tesserae of dark Basalt and other stones, Basalt made its architectural comeback at the turn of the 11th century, when a season of prosperity under the autonomous kingdoms known as *Giudicati* gave rise to a flurry of building activity. These builders dotted Sardinia, especially the Central Northern area, with churches built with Basalt, either alone or in conjunction with limestone and trachyte.

In the early centuries of the 2nd millennium, the island's master stonemasons, or *magistri lapidum* started associating and then forming trade guilds which provided mutual assistance and guaranteed the craftsmanship of their associates and the quality of the stone they used. Since then, generations of skilled craftsmen have adorned with their work the so-called 'Basalt towns' (Norbello, Ghilarza, Sedilo, Abbasanta) where basalt is king: as a building stone, for architectural details, and for paving streets and squares. More recently, the cultural revival of architectural stone and the new interest in this material



Ancient carved stone

1500 B.C

Above:
Drawing showing the underground layout of a small sacred well

Romanesque church at San Leonardo de Siete Fuentes (12th century)

Tomb of the Giants – approx. 1500 BC

The huge fine-picked upright stone dominates the site. At its base opens the entrance to the funerary chamber. (Photo: by kind permission of the Regional Tourism Dept).

Opposite:

Basalt mold

It was used to die-cast bronze tools (approx. 1500 BC).

Old masonry walls

Detail of a load-bearing wall in split face stone.

on the part of designers have spurred a growing demand for Basalt, especially in historic center restoration and enhancement projects, producing excellent functional and aesthetic results.

Today, the Basalt Industry of Sardinia proudly carries forward this ancient tradition. Fabrication, mostly done in-house by the quarriers themselves, is constantly evolving through the adoption of state-of-the-art technology and methods, enabling the local producers of Basalt dimension and ornamental stone to meet the most diverse design and installation requirements.

Chapter 3 - Sardinian Basalt

The ‘Basalt towns’

Houses built in brick-sized blocks and wall stone; the lintel and jambs are obtained from a solid stone unit; the face is sawn or fine picked, the other surfaces are split. The burnished metal railing harmonizes with the stone and leaves in full view the graceful architecture of the façade, with a slender but solid longitudinal arch. As is usually the case for this kind of arch, the stone units composing it are of uneven number.

Selection of quarried stone

The mechanical stresses to which the stone is subject during quarrying operations are in themselves a reliable indicator of the compactness of primary blocks.

Quarry site reclamation

Uniform grassland covers a reclaimed erratic boulder extraction site.

First squaring

The extracted stone is squared to obtain mill blocks.

Chapter 3 - Sardinian Basalt - *Quarrying and Fabrication*

Quarrying

Basalt produced in Sardinia for architectural and ornamental purposes is obtained by quarrying of stone deposits or mining of huge underground erratic boulders which are cut and extracted with mechanical equipment. Most often, the local extraction companies handle the whole production chain, from the quarry to the finished products. The island's basalt resources are virtually inexhaustible, as a large portion of Sardinia is made up, we might say, of a single extended basalt effusion, with varying degrees of fracturing.

The island's basalt quarries (there are currently 3 active quarries, with single or multiple ledge working faces) are located at sites with large outcrops and deep basalt tables. These plateaus have varying thicknesses (from 15 m to over 40 m) and can be profitably quarried (production of dimension stone and aggregate), also in the light of the excellent technical properties of Sardinian basalt. Quarrying/mining techniques utilize explosives and mechanical equipment. The stitch drilling and blasting method allows the splitting of large primary blocks, whose quarrying is then completed with mechanical equipment. Alternatively, the whole operation can be performed with mechanical methods only. This approach, although more cost-effective, is not always feasible, and unlike the first method, cannot take advantage of any fracture lines, which at times are not visible on the surface, to optimize production. Quarrying starts by dividing the deposit into sub-horizontal, functionally autonomous levels. The resulting rock mass is divided into vertical ledges, which are gradually quarried (generally using explosives for controlled extraction), divided into vertical slices or, if the type of deposit permits, into horizontal loafs. The degree of fracturing of the deposit affects the yield, i.e. the number of mill blocks obtained from a given loaf.

On the other hand, erratic boulders are extracted from the soil at the mining site using powerful mechanical shovels. Skilled machine operators are able right from this early stage to make an initial selection of the stone: the boulder's behavior under the pressure of the mechanical equipment can in fact provide clues as to possible fracturing or other defects. The huge basalt boulders are then loaded onto trucks and transported to the mill for fabrication. The site where the rock was extracted, thanks to the removal of the cyclopean blocks, can be reclaimed for agricultural use. The mining company usually also handles the reclamation process, re-establishing the topsoil and vegetation.

Cutting stock

Many articles can be obtained from these thicknesses: jambs, cornices, lintels, steps, etc.

Fabrication

Fabrication
Strip cutting

Rough Squaring

The quarried stone (quarry block or erratic boulder) is placed on a tracked trolley and sent for rough squaring, where irregular edges are cut off in order to obtain parallel, sawn sides. Squaring is performed with a single blade diamond saw, and produces roughly or well-squared blocks.

Block Cutting

The squared block is then cut by a multi-bladed saw with up to twenty vertical diamond blades, spaced to the required slab thickness. At each blade run, the depth of the cut is increased up to a maximum of 60 cm. Once the required cutting depth has been reached, the vertical blades are raised and a horizontal blade cuts off the individual slabs.

Slab thickness ranges from a minimum of 2 cm to over 40 cm, depending on the end product required. Slabs cut in this way are placed on benches and transferred to the cross-cutting machine.

To obtain slabs of thickness ranging between 10 and 40 cm, another machine can be used: a giant sawing machine with a single diamond blade 3 m in diameter, allowing cuts up to 40% of the disk circumference.

This cutter, which is subject to strong stress during operation, is mounted on a sturdy support anchored to the ground by a concrete base. Some plants also use machines which do not limit the height of the cut (chainsaws and diamond wire saws).

Of the cutting stock thus obtained (slabs and thick slabs or cubic stone) about 50 % is cut to size and finished at the producer's own fabrication plant while the remainder is sold to stone working companies for processing into finished products.

The basalt producers of Sardinia manufacture both a standard range of dimension stone (mainly for paving, flooring and facing applications) and a vast array of stone products made to order, according to designers' specs.

The high workability of Sardinian Basalt and the craftsmanship of fabricators ensure that virtually any request for special cuts and finishes can be met. For major work, the designer provides the dimension stone company with the sketches and fabrication parameters for his project, complete with clear and detailed drawings.

Chapter 3 - Sardinian Basalt - *Quarrying and Fabrication*

Cutting stock
Slabs stocked in the company's stockyard.

Fabrication and Cutting to Size

Strips and thicknesses are cut to size by a cross cutter, consisting of a bench with a guide that slides towards one or more diamond-tipped disks. Each strip, sprayed with an copious jet of water, runs along the guide until it reaches a preset cutting point, which provides the measure for the next cut. The sawn units obtained are used for paving, flooring and facing applications. Final cutting into precisely dimensioned elements (whether obtained from strips or from cubic stone) is executed by a bridge sawing machine. This machine, unlike the previous cutters, is equipped with a mobile bench that can both rotate and slide back and forth, achieving precision squaring and trimming of any type of edge.

SLABS - *Sizes (cm)*	
Thickness	min. 2, max. 40 or more
Length	depending on the block
Width	120 min / 250 max
Surface	sawn, honed, sanded, bushhammered

STRIPS - *Sizes (cm)*	
Thickness	min. 2, max. 40 or more
Length	depending on the block
Width	1 min / 40 max
Surface	sawn, honed, sanded, bushhammered

Tile line worker
The strips are cross-cut into flooring or cladding units.

Square section solid stone units

Surface Finishes

The surface finishes described below are those most commonly used for Sardinian Basalt. Each type of finish can be rough, medium or fine. Different custom finishes can also be made.

Bushhammering: this type of finish can be done by hand, using the bushhammer, a tool equipped with cusp-shaped tips, that cut into the surface of the stone to varying depths, producing different degrees of texturing according to non-slip requirements. In industrial production, bushhammering is performed by a pneumatic hammer with tungsten points.

Fine picking: by applying to the hammer head a plate equipped with sharp parallel blades, a fine picked surface is obtained, with varying degrees of texturing.

Sandblasting: this finish is accomplished by exposing the surface to a steady jet of sand or grit under pressure. It produces a uniform surface, of almost antique, luminous matte texture (thanks to the grinding of the vitreous component). Its non-slip properties depend on the particle size of the grit used.

Honing: this is performed by abrasive slurry honing machines and provides a smooth, luminous finish. It is a common finish for cladding panels and wall-facing tiles and in other architectural applications.

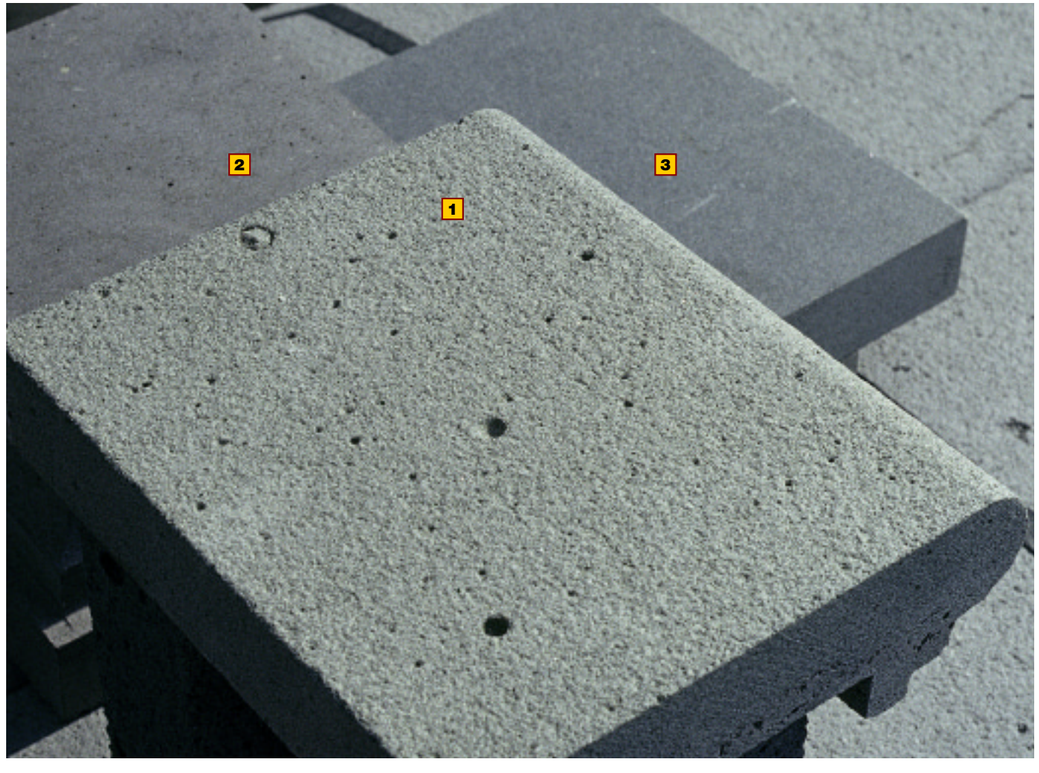
Hand Finish

Hand finishing is carried out by skilled craftsmen. Nowadays it is only done to order for special applications. The workbench is equipped with dust suction equipment, optimum lighting and a set of hand tools (mallets, chisels, bushhammers) and machine tools (cutting disks, drills, machine hammers).

Structural properties

The small vesicles found to varying degrees on the surface of basalt articles are not structural defects. On the contrary, they are the hallmark of this natural stone, and detract nothing from its durability and workability, revealing the fascinating natural history of this volcanic rock, one of the earliest building stones used in human history. Sardinian Basalt has excellent technical properties, which ensure the durability of its surface finishes. Its shades of color range from light to very dark gray or black, from wine red to dark red, and can be arranged in appealing combinations.

SOME TYPES OF FACE FINISH
1- Fine picked
2- Sawn
3- Honed



SARDINIAN BASALT	
Specific weight	2.21 - **2.981** g/cm^3
Density	2.2 - **2.9** t/m^3
Imbibition coefficient	**0.2** - 0.8 %
Compression breaking load	558 - **1800** kg/cm^2
Compression breaking load after imbibition	396 - **1705** kg/cm^2
Compression breaking load after freeze/thaw cycles	280 - **1265** kg/cm^2
Impact resistance (fall height)	**40** cm

The test results shown above are distinguished as follows: in bold type are the results for the more compact and less altered types of basalt. In plain type, the results for vesicular basalt.

Source: Geological Laboratory of the Cagliari Province

SARDINIAN BASALT

Masonry Stone
External Paving
Flooring
External and Interior Wall Facing
Architectural Features and Details
Street Furniture
Artistic Craftwork

The ‘Basalt towns’

Church (18th century) built of stone blocks and stone architectural elements. The church square is paved in Basalt and Gray Granite slabs.

Monumental bell tower in stone blocks.

Chapter 3 - Sardinian Basalt - *Finished Products*

Light and color effects

The same façade, seen at different times of day, shows the different hues of Basalt under varying light conditions.

Masonry Stone

House in brick-sized blocks, ashlars and wall stone
The lintel and jambs have sawn faces. Street paving in irregular paving stone (*Opus incertum*).

Brick-sized Blocks

Historically, *cantonetti*, or brick-sized blocks, were among the earliest types of basalt building stone. The blocks used in the early centuries of the second millennium to build the beautiful churches of the *Giudicati* period can trace their origin back to the well-squared ashlars, square or rectangular, (often with fine picked faces) used in the top courses of the ancient Nuraghi and Sacred Wells.

Today, Basalt is the building stone of choice not only for beautiful restoration projects, but also increasingly for new buildings where this very resistant versatile stone can be used for the entire structure or just for the façade.

Currently, basalt masonry blocks are rectangular, measuring 15x30 cm, with 15/18 cm thickness. They are produced with split surface and sawn beds or split on all sides. Each block weighs between 20 and 30 kg.

House in brick-sized blocks
A fine series of windows, framed by jambs and sills in thick basalt units.

Chapter 3 - Sardinian Basalt - *Finished Products*

Restored stone buildings
A restored farmstead and an old country church.

Wall Stone

Low-cost stone for wall building, roughly square or rectangular, with split and sawn faces. It comes in various sizes (10x20;15x10; 20x20;20x30;40x60 cm etc.). Minimum thickness 6/10 cm, maximum 35/40 cm.

External Paving

Basalt paved surfaces are to be found in the largest and most beautiful cities in the world, including those with very cold climates and long periods of frost, giving proof of this stone's excellent physical and mechanical properties.

A wide range of paving elements in Sardinian Basalt are available, both sawn and split faced. They all have very high breaking, compressive and wearing strength. Their thickness depends on the loads to which the paved surface will be subjected. The shape, sizes and finishing of all paving units in Sardinian Basalt may vary according to designer's requests.

Chapter 3 - Sardinian Basalt - *Finished Products*

Paving
Square paving with slabs of running length, 6 cm thickness and bushhammered upper surface.

Tiles
Private parking area paved with 30x30 cm tiles, with split sides, thickness 2 cm.

Paving
Courtyard paved with giant slabs (over 60 cm in length) in Basalt and Orosei Marble, thickness 4 cm.

Paving units in Sardinian Basalt

Tiles
Sawn slabs
Irregular split face paving (opus incertum)
Cubes
Square tiles
Setts
Tesserae for mosaic decorations
Cobblestones

PAVING SLABS - *Sizes (cm)*

Thickness	*Load*
2-5	pedestrian and cycle traffic
6-8	medium vehicle traffic
8-20	heavy vehicle traffic

Paving Tiles

Sawn tiles, square in shape, usually with sharp edges. The face may be sawn, bushhammered or sandblasted. They are also produced with split sides. Minimum size 5 x 5 cm, maximum 30 x 30 cm. Minimum thickness 2 cm. They are used to pave pedestrian areas, cycling paths and also driveways (pavements, courtyards, private parking areas, etc).

Sawn Paving Stone

Rectangular or square sawn pavers, with running length or defined according to standard measurements. Minimum standard thickness is 2 cm, maximum 8 cm (depending on the expected load).
As a rule, standard length of rectangular units, which ranges from 20 to 60 cm, is almost double their width. Sides are sawn and edges are sharp or smoothed. They

Chapter 3 - Sardinian Basalt - *Finished Products*

are also produced in other shapes: curved, hexagonal, heptagonal, triangular or round, to meet any designer requirement.

The face is usually bushhammered or sandblasted, to varying depths depending on the non-slip properties required. Basalt paving units provide a superior, versatile and attractive solution. This type of stone has excellent functional properties for paving squares and historic centers, walkways and driveways.

The 'Balsalt towns'

Paving and fountain in Basalt and Red Trachyte. A beautiful touch is given by the animal heads representing the signs of the zodiac, which serve as water spouts.

opposite:

Square

Slabs measuring 60x40 cm, 6 cm in thickness. Steps with bullnose edges.

Concentric paving design with Basalt and Trachyte setts (sides 15x10 cm, thickness 6 cm).

PAVING TILES - *Sizes (cm)*

Side x side	**Thickness**
Min. 5x5	min. 2
Max. 60x60	min. 3
Face	sawn - bushhammered - sanded
Sides	sawn or split face
Edges	sharp or chamfered
Back	sawn

LASTRAME PAVIMENTAZIONI ESTERNE - *Sizes (cm)*

Length	20 min / 60 max
Width	20 min / 45 max
Thickness	2 min / 8 max
Weight kg/m^2	3 cm thick. = 70 kg – 8 cm thick. = 200 kg
Face	to order
Sides	sawn
Edges	sharp or chamfered
Back	sawn

Custom sizes are also available, with different pricing, up to 100 cm in length and 20 cm in thickness.

Irregular slabs

This crazy paving blends in beautifully with the surrounding landscape in a parking and passage area leading to an archaeological site. In this case, small and medium sized units are used in the central rectangle, surrounded by giant units. The central units are antique finished while the giant stones have sawn face and split sides. The close up photo shows the warm violet tones of this type of Sardinian Basalt.

*Irregular Paving (*Opus Incertum *or Crazy Paving)*

Irregular paving slabs, made in different sizes, measured according to the median diagonal, and classified as Small, Medium, Giant and Cyclopean or Super Giant. The latter size type covers units exceeding 100 cm on the diagonal. Standard pavers range in thickness from 3 to 8 cm. They have sawn face and rough cut edges. Small and medium sizes are also produced with tumbled finish (antique finishing in the rock tumbling machine) with smoothed edges.

Decorative paving

The coat of arms of the 'Four Moors', made from irregular slabs of Basalt and Trachyte.

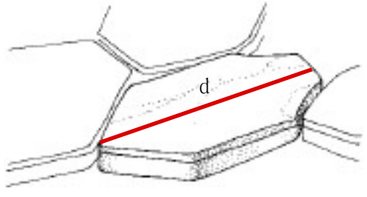
Cyclopean irregular paving

The longest diagonal of these huge paving units can exceed 100 cm (these larger sizes are used only for walkways and cycling areas)

This type of flagstone, low cost, functional and attractive is suitable for public walkways and driveways (the streets of historic centers, squares, pavements, parking areas, paths in green areas, etc.) as well as for private applications (terraces, backyards and front yards of luxury houses). Small and medium sizes, of minimum thickness 6 cm, can also be used to pave roads with intense vehicle traffic of medium-high load, provided special care is paid when laying the sub-base, vibrating and sealing (joints ± 2.5 cm).

Paving

Large irregular paving stones (diagonal 50/60 cm) in a pattern combined with cut units (granite slabs with medium-bushhammered face and basalt square tiles measuring 12x12 cm).



d = maximum diagonal.

IRREGULAR SLABS (Opus incertum) - *Sizes (cm)*

Size	thickness	diagonal	surface load
Small	3-6	10 / 15	light vehicle traffic
Small	6-8	10 / 15	medium vehicle traffic
Medium	3-8	15 / 25	medium vehicle traffic
Large	5-8	50 / 60	pedestrian and cycle traffic
Cyclopean	6-8	> 100	pedestrian and cycle traffic

Face	sawn - antique
Back	sawn
Edges	split - chamfered

- *Small and medium sizes are also available with tumbled (antique) finish.*
- *Greater thicknesses available on request.*

Basalt and Orosei Marble paving

Antique-finished setts, cm 3 in thickness, laid in running bond patterns, in combination with regular basalt and marble slabs. The well-laid rainwater drainage course surrounding the flowerbed is made of ready-to-assemble basalt units. See page 209 for a view of the fine-scored inner edges of the drainage slots.

Low wall

The top course is made of full thickness units, the sides are faced in 3 cm thick slabs.

Setts

These versatile elements are widely used to pave extensive pedestrian and cycling surfaces. They are rectangular in shape, measuring 6 x 15 cm and with minimum thickness 3 cm. They are also produced in 6 cm width and running length.
Setts can be supplied with split face (sharp edges and sawn back) or tumbled (antique finish and smoothed edges).
Both types can also be used to face low walls and for skirting.

Antique-finished setts
Composition with antique-finished setts framed by tiles measuring 10x10 cm.

Triangular unit
For flooring and interior wall facing applications.

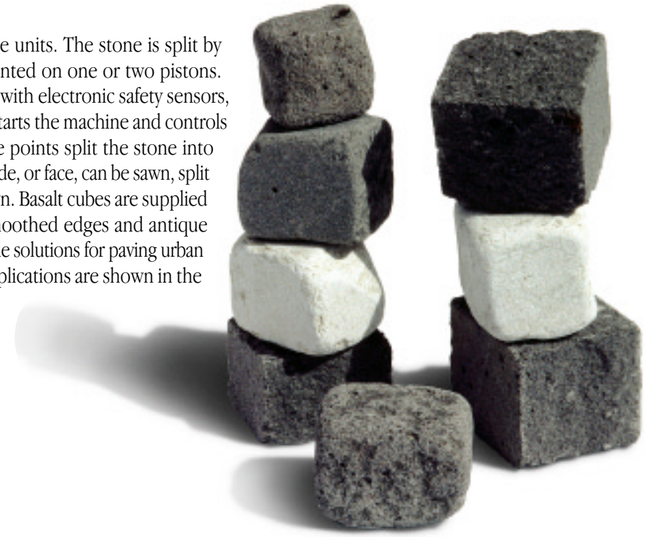
Split face setts
For paving and external wall facing.

Cubes
Basalt cubes of different size and finishing (standard and antique finishes). The top right-hand cube (without antique finish) clearly shows the difference between the sawn sides and the split top surface.

In theforeground: antique-finished cube (tumbled). The white units are antique-finished Orosei Marble cubes, often used in patterns with basalt cubes having the same finish.

Small Cubes

Split face cubes obtained from solid stone units. The stone is split by a cubing machine with widia points mounted on one or two pistons. The technician, wearing protective gloves with electronic safety sensors, places the stone unit on the work bench, starts the machine and controls the strike of the piston on the stone. The points split the stone into rough cubes with four split sides. The top side, or face, can be sawn, split faced or quarry faced, while the back is sawn. Basalt cubes are supplied with standard finish or tumbled (with smoothed edges and antique surfaces) offering designers a range of flexible solutions for paving urban and residential surfaces. Some of these applications are shown in the photographs on the following pages.



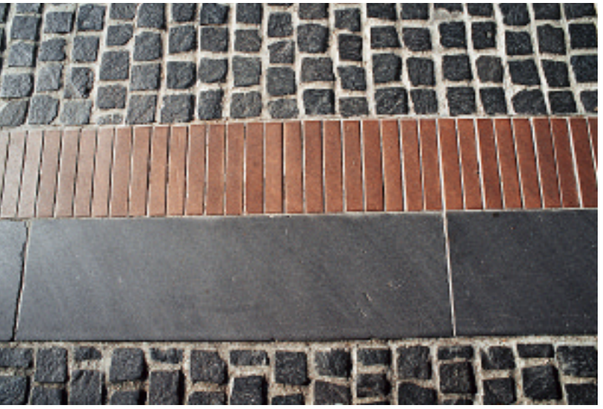
Standard cubes - Sizes (cm)	
Thickness or height	*Use (type of surface)*
Type 4/6	pedestrian
Type 6/8	medium-heavy vehicle traffic
Type 8/10	heavy vehicle traffic
Type 10/12	heavy vehicle traffic

SPLIT FACE AND ANTIQUE-FINISHED CUBES - *Sizes (cm)*				
Height/thickness	4÷6	6÷8	8÷10	10÷12
Side	4÷6	6÷8	8÷10	10÷12
Weight (kg/m^2)	80÷84	120÷125	155÷160	185÷190
No. of units/m^2	~380	~200	~120	~90
Weight of installed paving (kg/m^2)	90	120-130	160-170	200-210

Face	quarry face – split face – sawn
Sides	split face – sawn
Back	split face – sawn

- *Cube sizes 12//12,12/14 and 14/20 cm are also made to order.*
- In the antique type, all surfaces are antique finished.

Square tiles - *Sizes (cm)*					
Side x side	10x10	10x10	10x10	10x10	10x10
Thickness	3	4	5	6	7
Weight (kg/m^2)	70	95	120	145	170
No. of units/m^2	81	81	81	81	81
Face and back	sawn				
Edges	sharp				
Note: unlike split face cubes, square tiles are laid with perfectly even, flush joints.					



Cubes

Paving in split face cubes (installed in straight rows with running bond joints), combined with basalt slabs and edge-set bricks.

Square Tiles

Square paving and flooring units, 10x10 cm in size, thickness ranging from 3 to 7 cm, with sawn faces and joints and sharp arrises. Based on their thickness, they can be used for various types of flooring and paving applications, often combined with other cut stone (tiles, slabs).

The sawn sides ensure that the joints match exactly, unlike split side cubes. These units are mostly used to pave walkways and cycling paths. In greater thicknesses they can also be used to pave medium-traffic driveways. The tumbled type is also available, with smoothed edges and antique finish.

Chapter 3 - Sardinian Basalt - *Finished Products*

S'impedradu

S'impedradu is the Sardinian word for an ancient type of cobblestone paving. Many streets and squares of the island's old town centers were originally paved with a compact layer of small natural cobblestone, which was set in place by putting the elements very close to each other. In recent years, some basalt fabricators have started to produce stone for *s'impedradu* and this old type of cobblestone paving has been reintroduced in a number of local towns, blending in beautifully with the traditional architecture of the island's historic centers. *S'impedradu* can be used to pave walkways and light-traffic driveways.

S'impedradu

This is one of the many customized products from Sardinian fabricators. The photo shows paving rubble of 6/8 cm thickness, laid a few years ago.

Curbstones
Curved line curbs. Paving in *s'impedradu* rubble.

Cobblestones
80-90 kg of basalt cobblestones are required to cover a surface area of 1 sq m.

Cobblestone

Basalt cobblestone paving recreates the atmosphere of ancient Mediterranean cultures. Their soft, natural contours enhance any paved surface, both urban and residential. Cobblestones are obtained from basalt fragments of different shapes, smoothed and given an antique finish. Size ranges from 8 to 13 cm on the longer axis and from 4 to 10 cm on the shorter.

The cobblestone produced in Sardinia is easy to set in place and, unlike natural cobblestone, has a flattened surface, ensuring comfort for pedestrian and wheeled vehicles alike (including baby buggies).

Combined with other materials (slabs, cubes), cobblestone forms beautiful paving designs and is especially attractive when used in historic center renovation and enhancement projects.

Curbstones

Curbstones are rectangular in shape, usually of running lengths (on request, fixed length units are supplied). These very solid stone units, with straight or curved lines, are used to border flowerbeds, streets, pavements, and for architectural details. Standard curbstones are sawn on all sides, with the visible edges smoothed a few mm or rounded; the top surface (head) is sawn, sandblasted or bushhammered. If the area bordered by the curb is paved with thick stone elements, the thickness of the curb's hidden side can be gauged so as to avoid the wide joints that would be required when joining the curb to the paving stones. Curbstones whose lower part has been hollowed with a milling machine form rainwater catchment drains.

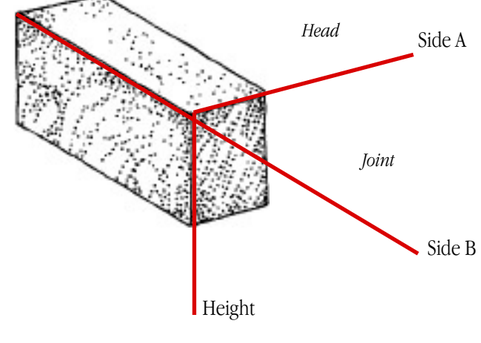
Chapter 3 - Sardinian Basalt - *Finished Products*

External Paving
Square-tile paving.

Running-length CURBSTONES - *Sizes (cm)*

SIDE A	HEIGHT	SIDE B
8	15	running
10	15	"
12	15	"
15	15	"
SIDE A	**HEIGHT**	**SIDE B**
8	20	running
10	20	"
12	20	"
15	20	"
SIDE A	**HEIGHT**	**SIDE B**
8	25	running
10	25	"
12	25	"
15	25	"

Running length: minimum 1.5 times the unit's width.
Standard curbstones have sawn head (to order also split face, sanded or bushhammered), sawn or split back and sides. Height can exceed 25 cm.



Terminology of curbstones
Face = head or tread
Back = bed
Wide sides = sides
Narrow sides = joints

Flooring

Sardinian Basalt makes excellent flooring material, supplied in sawn slabs of different sizes. Indeed, this highly workable stone can be sawn into thin slabs of various dimensions, precisely cut to size and gauged. Tolerances are in the range of ±4 mm; this way, any slight lippage between the joints when setting the slabs in place is offset by the smoothed edge. Basalt floors enhance and complete with their subdued elegance the interior of public buildings and museums as well as commercial and residential buildings.

Slabs

Flooring units with sawn surfaces and joints, of standard rectangular or square shape, minimum thickness 2 cm, and sharp or smoothed edges. The face is generally honed. Thanks to its gray and brown tones, Basalt can also make beautiful flooring designs in combination with other natural stone types, such as Orosei Marble and also Trachyte, of equal or different shapes and sizes (but always following a precise geometrical design). Combining dimension stone of different colors, grain and texture is a complex operation, requiring careful planning and accurate installation, but it guarantees strikingly attractive results; the floor itself becomes a furnishing element, preserving its expressive force over time. The photographs show just a few examples of the many compositional possibilities offered by basalt.

Two-colored flooring patterns

Hexagonal Orosei Marble tiles and Basalt inserts (thickness 2 cm).

Typical checkered design, with beautifully contrasted Sardinian Basalt and Clear Orosei Marble.

Chapter 3 - Sardinian Basalt - *Finished Products*

Flooring

Exclusive flooring for a prestigious retail outlet. Floor geometry is achieved by quadrangular stone units of different sizes: polished Orosei Marble slabs (40x40 cm) framed by Basalt strips and alternating with small Basalt and Marble tiles (12x12 cm).

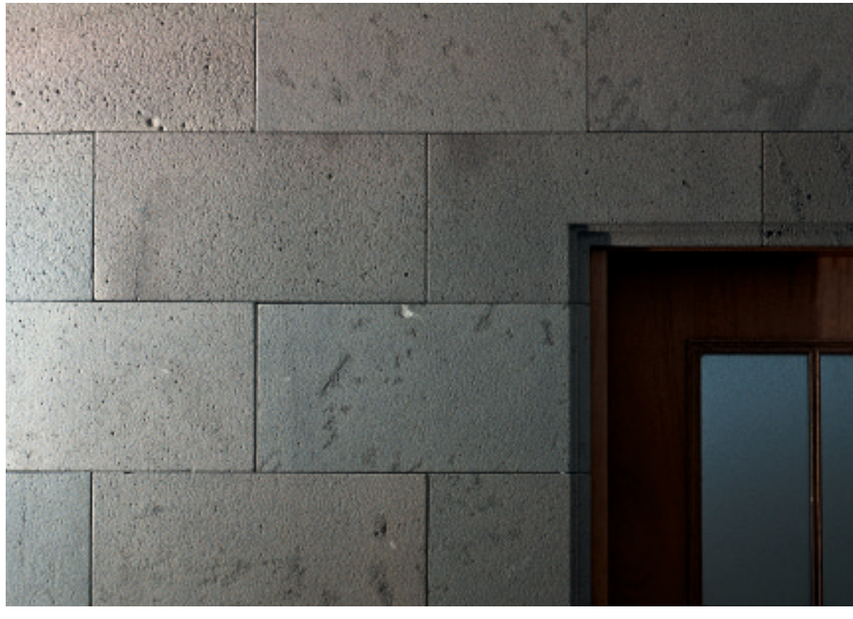
External and Interior Wall Facing

Full-thickness cornerstone
A perfectly cut article obtained from cubic stone.

Hollowed cornerstone
The inner surfaces and edges are sawn, the visible surfaces (not shown in the photo) are sawn or honed.

For exterior and interior wall facing applications, basalt is supplied in a range of sizes, shapes and thicknesses: thin, cut-to-size slabs, square or rectangular, of minimum thickness 2 cm, with various face finishes and sawn joints; sawn units of minimum thickness 6 cm, square or rectangular, minimum size 12x12 cm with sawn, split, rusticated or bushhammered face; or hollowed corner units, used to clad the corners of buildings, even to their full height.

Chapter 3 - Sardinian Basalt - *Finished Products*



Interior wall facing in Gray Basalt
Slabs for interior wall facing come in minimum thickness of 2 cm. The slabs shown in this photo are 4 cm thick to allow for the carved molding that frames the door.

Square

The boundary walls are faced with thick slabs of running length (thickness 15/20 cm), with coarse bushhammered face.

Chapter 3 - Sardinian Basalt - *Finished Products*

Wall facing

Square stone units (2x12 cm), with split, rusticated face. The sides and back are sawn. They are supplied in varying sizes and thicknesses, giving a stylish finish to internal walls, whenever a strong visual impact is sought. They are also suitable for various types of external applications (wall facing, base courses, etc.).

Above:

Pillar
Pillar made entirely of thick basalt blocks.

Interior wall facing
Detail of a molding.

Architectural Features and Details

The excellent workability of Sardinian Basalt makes it suitable for a wide range of architectural applications (lintels, pillars, capitals, balustrades, jambs, copings etc.).

Also in this respect, the 'Basalt towns' of the island offer a unique chance to discover just how basalt has been worked and used along the centuries. Architectural components in basalt are applied in fine public and residential projects, and in the restoration of ancient buildings.

Opposite:

Patio

Longitudinal arch: ashlars and capital are obtained from cubic stone

The 'Basalt towns'

Old stone-framed portal. The keystone is adorned by a lion's head, finely sculpted with mallet and chisel, below which are carved the initials of the master of the house. The color and design of the bronze portal beautifully match the stonework.

Window frame

The stone units that frame this window can also be used for fireplace surrounds, lintels and other architectural features. In this case, Basalt gives a stylish touch to a fabrication plant building, framing the window that offers a wide view of the production area.

House under construction

Finely matched architectural features in Basalt.

Balustrade

Stone balustrades, like the one shown here, make a stylish, solid finish that enhances the whole building. This balustrade is made of finely molded posts, topped by a handrail with linear molding.

Architectural element

Imposing, exquisitely carved lintel and posts.

Pillars

Max. height 200 cm, of square or round section, measuring from 10x10 to 30x30 cm.

Architectural features

A finely restored building with various basalt elements: lintels, jambs, window frames and chimney stack tops. The dark Gray Basalt contrasts beautifully with the color of the masonry, the attractive balustrades and the gleaming copper gutters.

Chapter 3 - Sardinian Basalt - *Finished Products*

Copings

Cope stone is used to provide a finished appearance and protect the top of boundary walls, fencing walls and brackets. It can also be used for interior finishing. It is obtained from slabs and strips of minimum thickness 6 cm and can be cut to required shapes. Length is running or defined, width and thickness are defined to order. Sides can be sawn or split, edges are sharp, smoothed or chamfered.

Pillar

Square section, height 220 cm, topped by a fine carved capital, with cusp-shaped cap.

Staircase with stepped skirting

The treads are 4 cm in thickness, with bullnose edges. The risers are recessed, with square edges.

House under construction

Tread with bullnose edges, one of the most common finishes for step edges.

Thick risers

Minimum thickness 6/8 cm.

Chapter 3 - Sardinian Basalt - *Finished Products*

Stairs

On these pages we show a few examples of staircases made of Sardinian Basalt. The treads of interior stairs are obtained from slabs of thickness ranging from 3 to 6 cm. The surface of the treads is gauged to the thickness required, with standard width of 5 cm (greater widths available on request) while the thickness of the remaining part of the tread has a tolerance of ± 0.4 mm. Surface finish of the tread can be chosen from the finishes available for Basalt. The finish of the visible side can be chosen among finishes available for tread sides (see pag.217). The riser, i.e. the vertical element of the stair, is obtained from a slab of 1 ÷3 cm thickness.
On request, curved, fan-shaped and triangular section stairs are also supplied.

External staircase

Steps obtained from cubic stone. Thickness may vary from 8 to 30 cm. Irregular paving with small and medium sized units.

Street Furniture

Street furniture
Retaining wall bordering an elevated flowerbed, made from blocks of Basalt and Clear Orosei Marble.

Based on designers' specs, the Basalt fabricators of Sardinia can produce urban furniture of any shape or size (planters, fountains, milestones, benches etc.). These pages show just a few examples.

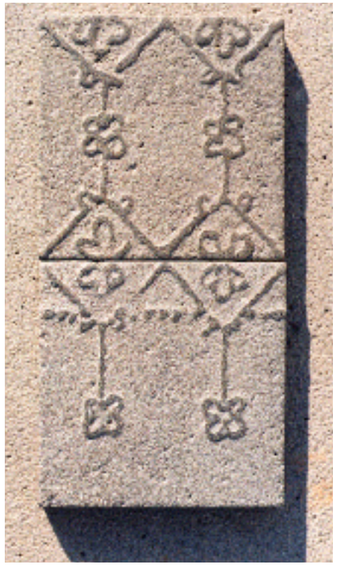
Chapter 3 - Sardinian Basalt - *Finished Products*

Bollards
Pair of bollards (in Basalt and Orosei Marble) with fine-picked surfaces.

Carved tiles
Carved tiles for wall decoration.

Artistic Craftwork




Basalt Granulate

Basalt granulate is used as component of asphalt and concrete and for making road sub-grade. It is obtained by crushing fragments from basalt processing or from rock quarried for this purpose from highly fractured deposits.
On these pages the steps in granulate production are illustrated, starting from quarried material, which weighs 25-26 quintals/cu m.
The rock is extracted by a power shovel equipped with pneumatic hammer, or by means of small explosive charges.
The crushing plant is located close to the quarry face, with input hole of 90 cm diam., cased in a reinforced concrete structure. Before conveying to the crushing mill, the basalt is broken into large fragments (diameter 70/80 cm). This occurs in part spontaneously as the stone drops from the quarry face and in part is caused by the equipment used for extracting the stone. The first standard product of the fragmenting process is a coarse granulate, called *tout-venant*. It is collected from the pile that forms at the foot of the mill by means of hoppers and is transferred through a

TYPES OF BASALT GRANULATE

Name	size-diameter (cm)	weight/m³ (quintals)
Tout-venant for road sub-grade	7 / 8	15 - 16
Mezzanello	3 / 4	“
Grit	± 2	“
Risone	±1	“
Pounce	microgranules	“

Delivery: in bulk, by truck

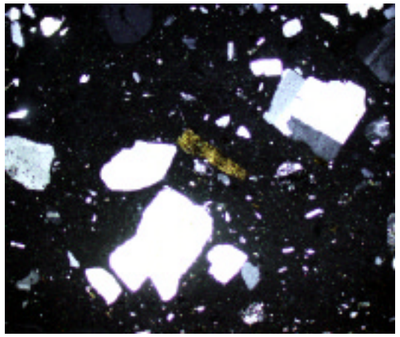
conveyor system to the other machines for producing different types of aggregate.
Mezzanello is used for road and railway sub-grades, in concrete production and to prepare the road base before laying the bitumen surface course.
Pounce is used to finish asphalt.
The coarser *Tout-venant* is used as a sub-grade under railway sleepers.

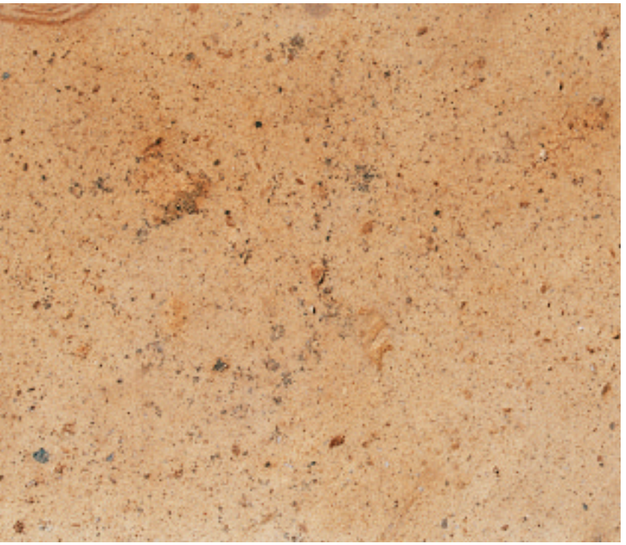
SARDINIAN TRACHYTE

Rhyodacitic pyroclast (thin section)
Quartz phenocrysts and feldspars, without definite shape; notice the colored biotite flake.

Below:
Yellow Sardinian Trachyte.

Geology and Stone Identification





The commercial name Trachyte covers a wide range of rocks, whose volcanologic-petrographic classification includes andesitic, dacitic, rhyodacitic, rhyolitic and trachytic pyroclasts, to mention only the most common. As regards petrographic classification, this group of rocks may be defined more correctly as pyroclastic.

Pyroclasts are extrusive rocks arising from the explosive fragmentation of volcanic material. They result from the deposition on the earth's surface of large amounts of magma that, in rising to the surface, also tore pieces from the country rock. According to their size, the fragments (pyroclasts) are named, in decreasing order: blocks, bombs, lapilli and ash. Pyroclastic materials mixed with gas form large dense clouds, which either rise into the atmosphere and then fall like rain, or flow like a land slip, down the slopes of the volcano. In both cases, they give rise to layered deposits, which are then consolidated by hydrothermal or diagenetic phenomena. Before erupting, the magma that will generate the pyroclastic material collects in a magmatic chamber where it usually becomes enriched with other silica and residual gases.

Pyroclastic rocks often have a porphyritic fabric, while their texture can vary: porphyroclastic, fluidal, eutaxitic or mycro-cristalline. Porphyritic fabric consists of distinct sizes of coarse and fine grained crystals set in a glass matrix: the larger crystals formed underground, while the finer ones formed on the surface. Texture is mainly conditioned by the type and force of the eruption and by the presence of gas in the magma. Macroscopically, pyroclastic rocks are anisotropic; they may contain numerous vesicles and pumices or may be compact (and also very glassy). Their color depends on the amount and chemical composition of the glassy matrix. As a rule, red or yellow signal the presence of iron, green is linked to copper, gray or white to high pumice and/or ash content. Color may also be influenced by the fragments of country rock. Mineral composition depends on magma chemistry and secondary alteration processes. Different minerals can be found in these rocks: quartz, K-feldspar, plagioclase, biotites, hornblende, pyroxenes, chlorites, zeolites. Sardinian landforms are often characterized by large volumes of pyroclastic rock belonging to the sequences that filled the Sardinian rift in the Oligo-Miocene periods, 33 to 13 million years ago. These rocks form outcrops in the following areas: the Sulcis district (Gonnesa-Portoscuso), the Mid Campidano plain (Serrenti), the territory of Bosa and areas of Central-Northern Sardinia (Fordongianus-Allai, Ottana, Sedilo, Ozieri-Oschiri-Osilo). In these areas, where the outcrops have little fracturing, we find the largest number of dimension stone quarries.

On the other hand, very glassy and highly fractured pyroclastic formations are quarried for granulate production.

Sardinian Trachyte
Detail of the Green-Blue type, somewhat rarer and used for up-market architectural and ornamental applications.

The Trachyte towns

Religious symbols carved on an old trachyte architrave.

Roman Baths

The *natatio*, or bathing pool.

Walled enclosure (approx. 2000 B.C.)

The trachyte wall was built to protect the small village within it, whose ruins can still be seen – as it stands today, the wall is 97 m long, 3-5 m thick and about 3 m high.

Historical Background

The name Trachyte comes from ancient Thrace, where the first deposits of this rock were discovered, and according to some sources, from the Greek word 'τρακίς', meaning rough or coarse. Trachyte was widely used as a building stone in ancient times: the Romans used it for paving, building construction and various architectural features. The Roman, and later Byzantine Baths of Fordongianus (1st-3rd centuries AD) are the most outstanding and best preserved example of the ancient applications of Trachyte in Sardinia. But the whole island is dotted with countless other ancient trachyte structures (such as defense walls, chamber tombs locally called *Domus de Janas* – i.e. Houses of the Fairies – and stone huts) while local museums display beautiful trachyte vases, mostly dating back to the Ozieri culture (Middle Neolithic, 3300 - 2500 BC).

In the areas of Sardinia where trachyte deposits abound, this stone has been used for centuries for building and decorative purposes: masonry work (houses, bridges, breast walls) urban design, architectural features (pilasters, capitals, lintels, sills, etc), statues and moldings. Many Sardinian churches were built (12th and 13th centuries) in Trachyte, at times alternating with courses of basalt or limestone blocks. This stone, striated with deep reds and pinks, bathes in a warm light the historical centers of the so called 'Trachyte towns' (Fordongianus, Bosa, Ittiri and the towns of the Logudoro district) and stands out in the solitude of the countryside where the only sign of human presence are the churches that at dawn and sunset glow with fascinating reddish tinges.

Chapter 4 - Sardinian Trachyte

Roman baths (Fordongianus)

To exploit the hot water springs, the Romans built a monumental Bath complex (1st-2nd centuries AD) entirely built with local trachyte stone, which was employed for masonry work, floors and paving, architectural elements, and the hydraulic system as well. The complex was served by a perfectly engineered system of conduits and channels, still today working and in use. Guided visits to the Baths are organized by the Youth Cooperative *Foro Traiano*.

Roman Pool

Detail of the pool paving (trachyte slabs, 40 cm thick).

Roman building techniques

Wall in alternating courses of small trachyte blocks and *opus signinum* (a mixture of ceramic fragments and lime).

Tiers in thick blocks

Notice the large calcareous concretion covering the central area of the steps.

The Trachyte towns

Aragonese-Gothic church (16th century) in masonry blocks. The portal is surmounted by a deep pointed arch, a hallmark of the Gothic style, with a large span. This arch, unlike other types of arches, consists of an even number of blocks. This is because pointed and lancet arches make it difficult to fit a single keystone, so that two keystones are used, and the joint between them forms the apex of the arch.

Aragonese house (16th century)

The 'Trachyte towns'

These photos show the astonishing versatility of Sardinian Trachyte as a building and ornamental stone. In a single church building, we find a whole range of applications, including solid masonry units, sturdy architraves, delicate moldings and *putti* (cherubs) and the finely carved statuettes that adorn cornices and niches.

Chapter 4 - Sardinian Trachyte

Quarrying and Fabrication

Quarrying
Quarry block cutter in operation. Cutting speed is 1m/2 min; maximum daily output is 200 sq m.

Detail of the quarry face

As stated in the subsection on geology and stone identification, the commercial name 'Sardinian Trachyte' covers a wide variety of pyroclastic rocks that henceforth will all be referred to by their common trade name.
Currently, the Sardinian market offers a number of trachyte stone articles, of different grains, hardness, compactness and colors (pink, red, yellow, gray, brown; less frequently, green-blue). Trachyte is quarried and worked by companies located in the provinces of Oristano (Ardauli, Bosa, Fordongianus, Ruinas), Sassari (Benetutti, Ittiri, Oschiri, Ozieri, Uri), Cagliari (Serrenti), and Nuoro (Sedilo). Sardinian deposits are usually extensive and only slightly fractured, with exploitable depths ranging from 10 to about 60 m. The most common and effective quarrying method is by single ledges and horizontal loafs. Quarrying proceeds downward, using quarry cutters mounted on tracks and equipped with two toothed sawing disks (one vertical, the other horizontal). Cutting speed is 1 - 2 m/min, with a maximum daily output of about 200 sq m. After appropriate preparation of the quarry yard, parallel lines are traced on the surface of the rock slice with the vertical blade. The cut is then made simultaneously by the two blades: the vertical disk has a maximum cutting depth of 40 cm, which determines the size of the primary blocks cut out of the quarry loaf (maximum size: 40x60 cm, and length according to requirements). Following this cutting method, other stone units as well as blocks can be obtained already during primary cutting in the quarry: solid stone for masonry work, strips of different thicknesses, or slabs for paving applications. Strips and slabs can be obtained also in the fabrication plant, by cutting the block with a bridge sawing machine with diamond-tipped disk.
On the other hand, the hardest and most resistant trachytes are quarried by diamond wire sawing, a system which produces perfectly whole, standard size blocks. The beauty of Sardinian Trachyte lies in its warms colors, whose intensity may vary even within a single quarry run, a single slab and therefore a single article, enhancing the unique character of this natural stone.

Step on the quarry bed
Here, a step has been made on the quarry bed to obtain – after the final horizontal cut – thick paving units already shaped by the vertical cut.

Depending on the type of vertical cut made on the loaf, it is possible to obtain strips, slabs, masonry blocks, thicknesses etc.

Blocks

Rectangular blocks (size 60x40x250 cm) ready for cutting and shaping into slabs, pillars, statues, thick steps, etc.

Fabrication

Sawing of the quarried stone.

SLABS - *Sizes (cm)*	
Thickness	min. 2, max. 40
Length	depending on the block min 40/max 250
Width	depending on the block
Surfaces	sawn, honed, bushhammered

STRIPS - *Sizes (cm)*	
Thickness	min. 2, max. 40 or more
Length	depending on the block
Width	min 1/max 40
Surfaces	sawn, honed, bushhammered

Chapter 4 - Sardinian Trachyte

Strips

They are sawn at the quarry or at the fabrication plant.

Raw masonry blocks

Obtained from quarry blocks; they measure 18x24x39 cm and weigh about 30 kg.

Thick stone units

Used to make jambs, frames, curbstones, fireplace surrounds etc.

Paving units

They are either cut at the quarry or obtained from strip cutting.

Pink Sardinian Trachyte

SARDINIAN TRACHYTE
Physical and mechanical properties

Weight density	1790 - **2550**	kg/m³
Specific weight	1.85 - **2.20**	g/cm³
Imbibition coefficient	**0.10** - 0.2	%
Compression breaking load	301 - **1319**	kg/cm²
Compression breaking load after freeze/thaw cycles	168.7 - **1158.3**	kg/cm²
Impact resistance (fall height)	29 - **70**	cm
Abrasion resistance (250 cycles)	**6.49**	mm
Abrasion resistance (1000 cycles)	**24.81**	mm
Bending modulus of rupture	**86.00**	kgf/cm²

The values in bold type refer to the hardest and thickest Sardinian Trachytes; the values in plain type pertain to the softer and less compact types.

Sources: 1) Geotechnical Laboratory, Cagliari Province. 2) Material Testing Laboratory, Dept of Structural Engineering, Cagliari University. 3) Test results attached to the Quarry Licensing Applications submitted to the Regional Quarry Office

Comparison between the physical and mechanical properties of Sardinian pyroclasts and some Italian trachytes and pyroclasts

Physical and mechanical properties		**Sardinian Pyroclasts**	**Peperino*** Pink	Soft Gray	Medium Gray	Hard Gray	**Euganean Trachyte****
Real density	**kg/m³**	2,482-2,603	2,590	2,630	2,630	2,630	2,669
Apparent density	**g/cm³**	1,533-1,865	2,260	2,090	2,230	2,320	2,405
Real porosity (w. respect to volume)		24.85%-40.92%	12.7%	19.9%	15.2%	11.8%	9.9%
Imbibition coefficient (w. respect to mass)		0.100-0.206	0.124	0.096	0.043	n.d.	0.027
Compression resistance	**MPa**	15.2-86.6	31.9	20.0	35.2	48.7	102.3
Abrasion resistance (Amsler)	**mm**	7.8-19.2	20.2	17.6	6.6	n.d.	5.3
Impact resistance	**cm**	38.8-77.5	n.d.	n.d.	40	n.d.	51

* Peperini del viterbese *(Pinzari et al.,1986).*- **Trachiti euganee *(Calvino,1969).*

Table taken from: Le piroclastiti sarde come pietre ornamentali *by Giorgio Massacci and Cesare Medici (Proceedings of the Conference* Le materie prime minerali sarde *published by CUEC - Cagliari 1997).*

SARDINIAN TRACHYTE

Masonry Stone

Internal Wall Facings

External Paving

Architectural Elements

External and Interior Finishings

Artistic Craftwork

Street Furniture

Bridge
The arches are made of masonry blocks.

Restored house
Load-bearing walls are built of irregular trachyte stone; lintels, jambs and thresholds are in dressed trachyte.

Masonry Stone

Masonry Blocks

These exceptionally durable rectangular units are used in public and residential building projects, for boundary and breast walls and monument restoration projects In the latter case a geologist needs to be consulted to ensure the durability of the restoration.

Various types of building blocks are available, with different surface finishes: coarse – from primary quarry cutting; smooth – with sawn surfaces; rusticated – by manual picking, with sawn sides and backs; bushhammered or fine-picked face – with sawn sides and back.

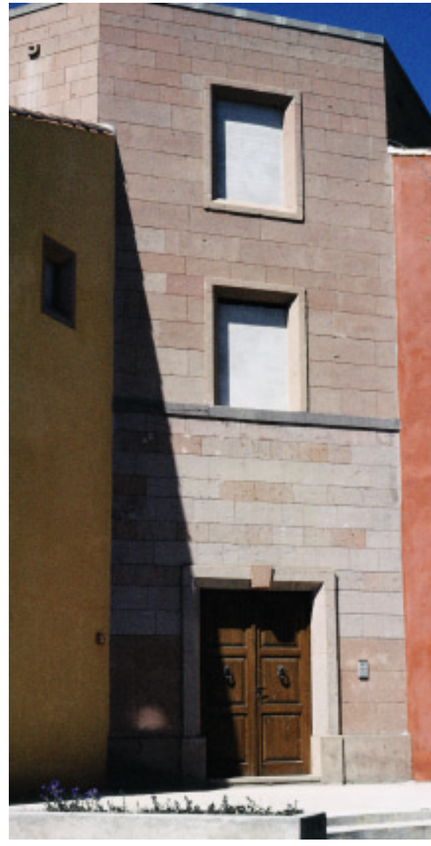
Standard size of a trachyte building block is 24x39x18 cm, weight is about 30 kg. Larger or smaller sizes can also be supplied to order, as well as different shapes, such as cubes of various sizes or custom-shaped units.

The 'Trachyte towns'
Building (16th century) with walls in irregular trachyte blocks and trachyte window frames.

Masonry block
The upper surface is rusticated, the other surfaces are sawn finished.

Modern style building
Masonry blocks with sawn surfaces and trachyte lintels and jambs.

Load-bearing wall
An appealing effect is obtained by alternating masonry blocks of Pink and Blue Trachyte.



Wall facing

Internal wall faced with honed rectangular and square tiles (size 20x20,20x30 and 25x30 cm; thickness 2 cm; sharp edges; joints 2 mm).

The decorative piece is a hand-carved slab, obtained from a 3 cm thick unit.

Chapter 4 - Sardinian Trachyte - *Finished Products*

Interior Wall Facings

Sardinian Trachyte is used for interior wall facings with excellent aesthetic results. Thin wall panels enhance the warm color and fine volcanic texture of Trachyte, giving an incredibly appealing, stylish finish to public and private interiors.

For internal wall facings, panels of different shapes and sizes are produced. Minimum thickness is 2 cm, with sawn sides and sharp edges. The back is sawn, while the visible surface is usually honed (unless otherwise requested).

The beauty of Sardinian Trachyte lies in its changing colors, whose intensity, due to the natural character of this stone, may vary even within the same panel.

EXAMPLE OF SUPPLY SPECIFICATIONS
Internal Wall Facing in Sardinian Trachyte Slabs

Supply and installation of internal wall facing in Sardinian Trachyte, in slabs of various sizes, thickness 2 cm, with honed face, sawn back, sides sawn to 90 degrees and sharp edges. The slabs shall be installed, according to project drawings, with cement mortar in the ratio of 250 kg type R 3.25 cement to 1 cu m of sand of the appropriate grain size (or appropriate glue).

Supply price shall include the following work: cost of supply and laying of the mortar; sealing of the joints; repairing of plaster as needed; finishing around window and door frames; replacement of any slabs broken or chipped during installation; subsequent surface cleaning, cutting, trimming and any other operation required for a workmanlike execution.

No.	20x20 slabs, thickness 2 cm
No.	20x30 slabs, thickness 2 cm
No.	25x30 slabs, thickness 2 cm
Cost Euro/m^2	

See page 196 for other examples of supply specs.

Detail of trachyte wall facing

Honed slabs, size 25x30 cm; thickness 2 cm, sharp edges, 2 mm joints. The slabs are arranged in a design with sawn square tiles (size 12x12 cm and thickness 2 cm) and triangular tiles.

Endless decorative patterns can be obtained by combining differently shaped units, also with different surface finishes.

External Paving

Sardinian Trachyte is also used for external paving. Indoors, it is most often employed as a wall facing material, while for flooring it is less used, usually to add a decorative touch to floors tiled with other stones.

For external paving, various stone units are produced, for pedestrian areas and driveways. Trachyte curbstones are also produced, in various sizes and finishes, to complement paving projects (for curbstone details please refer to the chapter on Basalt curbstones).

To preserve the distinctive colors of this stone, paving units can be coated with impregnating agents to protect their upper surface from staining and dust. Producers can advise buyers on the best type of agent and its application.

Paving Slabs

Sawn units, of rectangular or square shape, min. thickness 5 cm. Rectangular slabs range in length from 10 to 60 cm and their length is usually almost double their width. The sides are sawn and edges are sharp or smoothed. Trachyte paving slabs are mostly used for pedestrian and cycling areas (squares, sidewalks). However, thicker units can also be used to pave driveways.

Thicknesses of Trachyte external paving slabs
(According to load type).

Thickness (cm)	Surface and load
5	Walkways and cycling areas
10	Medium wheeled traffic
20	Heavy wheeled traffic

Chapter 4 - Sardinian Trachyte - *Finished Products*

PAVING SLABS - *Sizes (cm)*

Side x side		Thickness
Min.	10 x 10	5
Max.	30 x 60	15 / 20

All intermediate sizes of square or rectangular slabs available.

Face:	sawn or bushhammered
Sides:	sawn
Back:	sawn

One sq m of paving of 5 cm thickness weighs 100 kg. Weight increases by 20 kg/m² with each additional cm of thickness.

Square

Gray trachyte paving framed by basalt slabs. The fountain is built with trachyte stone.

Crazy paving
Tumbled elements (small size) of Red Trachyte and Basalt.

*Irregular Paving Units (*Opus incertum *or crazy paving)*

Units with sawn upper and lower surfaces; usually they have 5 irregular sides, three of which derive from the first quarry cut, while the other two are split.
The most frequent finish is antique (tumbled), with mechanically smoothed edges. These irregular pavers are used for external surfaces, especially pedestrian areas (walkways in historic centers, courtyards, parking areas).
They can be laid in patterns with other types of stone cut in similar shapes (usually Basalt or Marble). Thickness ranges from 5 to 8 cm, depending on the estimated load on the paved surface; thicker units can be supplied to order.

***IRREGULAR SLABS (*OPUS INCERTUM*) -** *Sizes (cm)*

Size	Thickness	Diagonal	Use *(surface load)*
Small	5	10/15	pedestrian
Small	8/10	10/15	medium wheeled traffic
Medium	5	15/25	pedestrian
Medium	8/10	15/25	medium wheeled traffic

Face and back: sawn.
Weight of 5 cm-thick units: 100 kg/sq m.
Weight increases by 20 kg/sq m for each additional cm of thickness.

Small square-faced units and tiles
The items to the left have sawn surfaces and sharp edges; those to the right are tumbled (antique finished), with smoothed edges.

Small Square-faced Units

These units are obtained from waste from block cutting, finished in the stone tumbler to obtain antique surfaces and smooth edges and sides. They are produced in different sizes, starting from 3x3x3 cm (side x side x thickness).
The 10x10 cm size, thickness 7 cm, is suitable for paving large surfaces, similarly to cubes of other stone types.
These paving units are especially attractive, producing very striking results in decorative paving designs and mosaic inserts. They can also be laid face up or edge set for internal and external wall decoration purposes or can be used for countertops in public venues and kitchens, or for stylish masonry barbecues.

***SMALL SQUARE-FACED UNITS -** Sizes (cm)*

Side x side	Thickness
3x3	3
8x8	3
10x10	3-4-5-6-7
6x12*	3

**May also be edge set.*
5 cm thick units weigh 100 kg/sq m. Weight increases by 20 kg/sq m with each additional cm of thickness.

Sawn Square Tiles

Small square tiles, with sawn surfaces and sides, also available with antique finish and supplied in various sizes. Smaller sizes are: 1x1, 2x2 and 4x4 cm, thickness 1 or 2 cm (used for mosaic inserts, flooring, internal wall facing and decorative furnishings. The largest standard size is 12x12 cm, thickness 2 cm (used for geometric decorations on small pedestrian surfaces and for internal and external wall facing).

Small square-faced units

The photo shows the 6x12x3 cm type, edge-set on the side of a well, with a pleasant aesthetic effect.

Sawn square tiles

This is the largest standard size, sides 12x12 cm; thickness 2 cm.

Architectural Features

Trachyte blocks and thicknesses can be fabricated into a vast array of architectural elements, with different surface finishes: jambs, lintels, pilasters, sills, balustrades, capitals, cornices, copings, caps etc.

A number of Trachyte churches and buildings have been restored with excellent results using these elements, fully regaining their original splendor in many old towns in Sardinia.

Most common finishes for this type of article are honing (with abrasive paste to obtain a perfectly smooth, non-reflective surface); bushhammering (using the bushhammer to produce varying degrees of textured non-slip surface); picking (manually carried out with mallet and chisel, which produces a finely textured finish of varying depth).

Interior wall facing

Honed slabs of different shape and size surround and enhance the slender round arch (typical of Roman, Romanesque and Renaissance architecture), obtained from cubic stone and with honed visible surfaces. In the foreground, old stone implements once used for crushing olives.

Some types of architectural features

Small honed pillar (smooth).

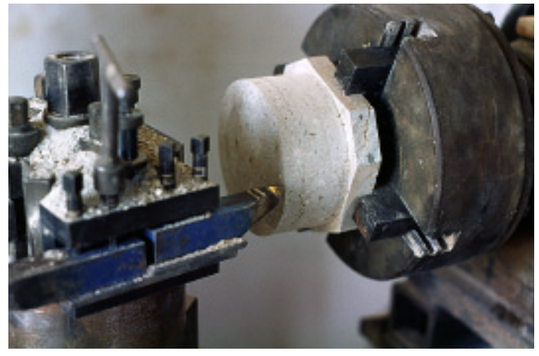
Bracket and shelf.

Jambs and lintel: the right jamb is honed, with sharp edges; the left jamb is fine picked, with smoothed edge.

Short, fine-picked pillar, with bushhammered cap.

Architectural features

Caps of different shapes and finishes.



For special shapes, the designer must provide a model (scale 1:1) of the requested article.

Sardinian Trachyte companies, many of which both quarry and fabricate the stone, can provide the technical consultancy required for optimum installation of all articles produced.

External and Interior Architectural Details

Stairs are the most frequent type of external and interior architectural detail. The examples shown on these pages are steps with overhanging tread and recessed riser (see page 217 for tread types). The units for this type of application are obtained from slabs of minimum thickness 3 cm (for treads) and 2 cm (risers). Stairs can also be supplied to order in non-standard shapes (triangular, fan-shaped etc.) and various thicknesses, ranging from very thin units for internal stairs to over 15 cm- thick units for external stairways. The visible surface of the tread is gauged to the required thickness, and has a standard width of 5 cm (or more) while the remaining part has a tolerance of ±5 mm.

Opposite:
Treads
From top:
Molded edge
Step edge
Bullnose edge
Half bullnose edge
Square edge
Surface finish: honed

The gently curving staircase pictured on this page is a beautiful example of external architectural application; the burnished metal handrail perfectly matches, as few other materials do, the stone artifact. The tread consists of a single honed slab, of 6 cm thickness, with bullnose edge and milled sides. In the foreground of the photo below, we can appreciate the finely finished edges of the wall coping. Stairs often enhance, as is the case with this example in trachyte, the unique functional and esthetical properties of natural stone.

Interior applications

Below:

Elegant stone fireplace with slabs, mantel, small pillars and capitals in Red Trachyte.

Fireplace, sconces and mirror frame in different shades of Sardinian Trachyte.

Among the different types of interior applications of Sardinian Trachyte, we should also mention fireplace surrounds, obtained from thicknesses that are variously shaped and finished, while slabs and thin panels are used to face or pave the fireplace itself. Custom fireplace surrounds can also be hand made and supplied according to designers' specifications. For articles including perforated stone inserts, the designer should provide the fabricator with a wooden mock-up of the requested perforated design.

Small pillars made for fireplaces can be of round or square section. Larger sizes are obtained from solid stone units of 27x39x100 cm (side x side x height), with the traditional mallet and chisel technique.

Different surface finishes

Below:

All surfaces are picked.

Right:

Picked and honed surfaces.

Artistic Craftwork

A wide range of artistic handicrafts are produced in trachyte, including relief wall panels (hand-carved from thick slabs) and hand-carved tiles which are applied as decorative elements on internal walls, combined either with plain trachyte tiles or with other wall facing materials.

Over the last few years, many stone workshops have been set up; they use small colored Trachyte tesserae to produce mosaic decorations, ready for installation for flooring and facing applications; examples include cornices, table tops and countertops, lamp pedestals, tracery work, table insets and many other furnishing applications.

Opposite:

Craftwork

Hand-carved panels and tiles for wall decoration.

Decorative panel

Beautifully carved decorative wall panel (70x60 cm), hand made from a 5 cm-thick slab. With the same precision and skill, panels can be carved with letters, mottos and street numbers.

Craftwork

Stone bowls in different diameters, thicknesses and heights, made with the mechanical lathe and hand finished. Diameter range is 8 – 50 cm, height 3 – 20 cm.

Craftwork

These small hand-made sculptures are just one example of the endless range of artistic articles for interior decoration created from Sardinian Trachyte.

Opposite:

Wall fountains

The moldings and surfaces are hand-dressed.

Bench

It has smoothed sides and edges, with honed upper surface; the legs have sharp edges and bushhammered surfaces.

Street Furniture

Example of Supply Specifications

External Paving in Sardinian Trachyte slabs

Supply and installation of ***Sardinian Trachyte paving slabs measuring 30x40 cm, thickness 5 cm, with sawn face and back, sides sawn to 90 degrees and sharp edges.*** The paving shall be installed, according to project drawings, on a 6 cm-thick cement mortar base course, in the ratio 250 kg type R 3.25 cement to 1 cu m of sand of the appropriate grain size.
The slabs shall be supplied with face pre-sealed with appropriate impregnating agent.

Supply price shall include the following work: supply and laying of the base course with a surface cement coating – not less than 6 kg/sq m; establishment of the required gradient for rainwater drainage; vibrating; replacement as needed of any slabs broken or chipped during laying; sealing of the joints with cement grout and sand; subsequent surface cleaning with sawdust; cutting, trimming and any other operation required for a workmanlike execution.

• ***Preparation of sub-base not included***

Cost Euro/m²

External Paving in irregular Sardinian Trachyte slabs (Opus incertum)

Supply and installation of ***Sardinian Trachyte*** paving, ***in irregular slabs of different sizes, thickness 5 cm, antique finished surfaces and smoothed edges.*** The paving shall be installed, according to project drawings, on a 6 cm-thick cement mortar base course, in the ratio 250 kg type R 3.25 cement to 1 cu m of sand of the appropriate grain size.

Supply price shall include the following work: supply and laying of the base course with a surface cement coating – not less than 6 kg/sq m; establishment of the required gradient for rainwater drainage; vibrating; replacement as needed of any slabs broken or chipped during laying; sealing of the joints with cement grout and sand; subsequent surface cleaning with sawdust; cutting, trimming and any other operation required for a workmanlike execution.

No. of small units (medium diagonal 10/15 cm, thickness 5 cm)
No. of medium units (medium diagonal 15/25 cm, thickness 5 cm)

• ***Preparation of sub-base not included***

Cost Euro/m²

APPENDIX

Types of External Paving

This section provides a brief overview of the main types of external paving used over the centuries: tamped earth, gravel, cobblestone, cubes, and flagstone. The first two do not use stone elements whereas the others utilize respectively cobblestone, cubes and slabs of various sizes.

Cobblestone

Cobblestone was the first paving technique employed by Man; it is the forerunner of all the mosaic arts (true mosaics and other types of composition using 'tesserae') and in ancient times it was known as *Opus barbaricum*. It was based on the use of naturally-rounded pebbles (from rivers or the sea) which were laid in a close-set pattern on a base course of tamped earth. It differs from flagging as the latter made use of worked stone units. Cobblestone was widely used from the 17th century onwards in place of tamped earth, the most common surface for roads and squares in European cities, while stone paving was reserved for the main roads only.

Natural cobblestones and granite guide strip

The granite slabs have deep indentations ensuring very good non-slip properties.

Cobblestone paving generally included guide strips in stone slabs, which served a double purpose: they assisted the passage of carriages and helped preserve the cobbles from undue wear. Guide strips are still used in today's cobbled streets to help the passage of motor vehicles. Cobblestone, as a result of surface permeability and laying method (dry set over a sand course) ensured only the surface drainage of stormwater. This feature comes in useful nowadays when, in order to allow the transpiration of urban areas with plant growth, it is necessary to mitigate the waterproofing effect caused by nearby asphalt or black top surfaces. A number of Italian cities conserve under the black top surface their ancient cobblestone; many of them have carried out successful redevelopment projects bringing back to their historical centers this ancient form of urban paving, achieving extremely attractive results.

Today, cobbles are obtained from small stone fragments, which are rounded and given an antique finish in the stone tumbling machine. From Basalt and Orosei Marble it is possible to obtain rounded or oblong cobbles, from Granite, cobbles of roughly rectangular or square shape. Thanks to their research into new production lines, Sardinian fabricators now produce cobbles which, unlike naturally shaped ones, have a flattened, regular surface face, easy to walk on or travel over.

Cobbles are extremely versatile elements: their small size and irregular shape make it possible to install them (often in compositions with cubes and slabs) both in regular geometric patterns and in other creative designs.

Cobbles of different colors (Basalt and Orosei Marble or Granite cobbles of different tones) may be used to create appealing geometric patterns, decorations or chromatic effects. Thus, the cobbled surface, especially with Granite, can take on different shades according to the slant of light.

Cube paving

The basic unit for this type of paving is the split face stone cube, which in ancient times was hewn from a whole slab using mallet and chisel and is today produced by cubing machines, in different sizes. Cubes are used to pave pedestrian walkways (squares, sidewalks, terraces, yard areas) and also for vehicle traffic zones.

The most ancient cube paved areas in Italy are to be found in the historic center of Rome and were installed starting from 1800, using Basalt cubes (which in Rome are called *sanpietrini*) quarried in the area round the capital. The paving of large areas with granite cubes became widespread in the late 19th century: the first of these large paving projects dates back to 1880 (Hanover, Germany). During the same period, basalt and limestone cube paving spread in Portugal and Spain and later in South America, where these types of stone were locally available in large amounts. The traditional Sardinian cube paving, *s 'impedradu*, has much more ancient origins: it consisted of naturally shaped stone units, approximately cubic or oblong in shape, which were laid closely set together.

At the present time, split face cubes are produced from the following types of Sardinian stone: Granite, Basalt, Orosei Marble and Trachyte. The granite cubes have all six sides split-faced; the cubes made from other types of stone may have different characteristics, details of which are given in the chapters on each stone type.

The edges of split face cubes are irregular and the faces may not form precisely

Paving in Granite and Basalt Andesite cubes

The cubes are laid in circular patterns, an attractive upscale design.
Geometric plan on page 219.

Appendix - Types of External Pavings

square angles. Cube paving must use types of stone which are particularly resistant to compression (before and after freeze/thaw cycles), to wear and to blows. For pedestrian and vehicle use, cubes in Basalt or Granite are used; cubes in Orosei Marble, excellent for their qualities of hard wearing and resistance, are often combined with Basalt or Trachyte cubes in the paving of squares or sidewalks. Compositions using two colors are also effective to trace pedestrian crossings, road markings etc.

Split face cubes can be given an antique finish and smooth edges in the tumbling machine. These tumbled cubes are used above all for pedestrian areas because of their smoother surface.

The cubes are classified in different standard types, depending on the thickness of the stone unit from which they are split (e.g.: from ≃ 9 cm thicknesses = cube with 8/10 cm sides). Size tolerances are useful for laying when, as in the segmental arch design, the installer needs both large and small cubes within the same size range.

To order, cubes with lesser tolerances may be supplied. Cubes installed on a sand base course also have the advantage of easy removal and total recovery of the cubes themselves in the event that works beneath the surface need to be carried out.

** Splitting is made possible by the presence in many stones of natural cleavage planes almost parallel to their bed.*

Standard cubes - Sizes (cm)

Thickness or height	*Use (surface loads)*
Type 4/6	pedestrian
Type 6/8	medium wheeled traffic
Type 8/10	heavy wheeled traffic

Types 10/12,12/12 12/14 and 14/20 are produced to order.

Concentric paving design

Made with Basalt and Orosei Marble slabs.

Pavings
Zebra crossing in Basalt and Orosei Marble slabs; paving in thick Granite pavers.

4/6 cubes make the paving design easier to perceive at a close distance (from 'the pedestrian's point of view'). Types 10/12,12/14 and 14/20 - frequently used in the squares of Central-Northern Europe - may need joints up to 2 cm, for which reason the pavement might appear less well-finished but it is very effective for areas such as archaeological parks, courtyards etc. Size 14/20 is used for the so-called *pavé*, very widespread in France and the Low Countries.
The cube is a stone element which best allows the designer to give free rein to his fantasy; cubes of a single stone type or compositions of cubes of different types of stone (Basalt and Orosei Marble or Basalt and Granite) offer endless design possibilities. These cubes moreover form a surface course which is extremely flexible and is perfectly adaptable to any irregularities (hollows, thresholds, embrasures or drains) which might be found along the edge of the road or on the surface to be paved.

Flagstone Paving

The term flagstone brings to mind the majestic pavements with which the Romans adorned the cities of their Empire. Nowadays, flagstone is the most widespread type of urban stone pavement, for its overall strength, variety of laying designs and easy installation. The units used for present-day flagstone surfaces are either square or rectangular (non-standard shapes may be provided to order) with varying thickness (up to 20 cm) according to the expected load. Large flagstones, less resistant to pressure than medium-small types, are more suitable for pedestrian walkways. The flagstone face finish (flamed or bushhammered) is also chosen on the basis of load type. In particular, deep bushhammering

Appendix - Types of External Pavings

Star design
Marble and Trachyte units; paving in Basalt setts.

Two-colored design
Basalt cubes and irregular Orosei Marble stone.

provides a textured finish which improves the adherence of vehicle wheels. Moreover, in flagstones of adequate thickness, this treatment can be repeated several times by slightly lowering the stone surface. Granite or Basalt flagged areas are to be found in the historical centers of some of the most beautiful cities in the world, in climates which run the range from great heat to extreme cold. Amongst Sardinian stone types, Granite and Basalt are the rocks most suitable for the production of elements for use as pedestrian and vehicle flagstone areas, because of their overall resistance and the typical roughness of the surface which is maintained even under heavy traffic. Orosei Marble and Trachyte are on the other hand used almost exclusively for walkways. However, Trachyte units of adequate thickness can also be used for driveways. The stone types described in this Handbook can also be used for irregular paving (*Opus incertum* or crazy paving), used for walkways and driveways. Basalt crazy paving is available in small, medium, giant and Cyclopean sizes; in the latter case the maximum diagonal of the slabs may even exceed 100 cm.

Thick paving slabs
(Granite, Basalt, Marble, Trachyte) depending on load type.

Thickness (cm)	Load
2 - 5*	pedestrian and cycling traffic
6 - 8	light to medium wheeled traffic
8 - 20	heavy traffic

** for Trachyte: minimum 5 cm; for Marble: minimum 3 cm.*

Depth of bushhammering (mm)	
2 ± 4	(fine pointed: walkways and cycling areas)
5 ± 8	(medium pointed: medium and heavy wheeled traffic)
> 10	(rough pointed: very steep driveways)

Notes on Paving Stone Laying

Foundation Soil and Sub-base

Before laying external paving in worked stone elements (cobbles, cubes, regular or irregular slabs) in order to ensure its durability over time, it is necessary to evaluate carefully the foundation soil* and prepare a sub-base** of suitable resistance and thickness (see information sheet 'Foundation soil and sub-base' on page 210).

The sub-base will clearly be lower than the level of the finished pavement and its thickness will be based on the several centimeters of sand or cement mortar requested for the base course according to the type of stone element; to ensure the compactness of the sand course, this should be coarse grained, clean and without clods of earth or salt (the use of sea sand is definitely not advised).

* Foundation soil: any natural layer of terrain without additions.
** Sub-base: a course which is slightly compressible (or not compressible) interposed between the foundation soil and the base course.

Laying Cobblestone Paving

Traditional installation (dry set cobblestone): using a mallet, the cobbles are set in a sand course about 10 cm thick laid over a sub-base of tamped earth. After the first hammering with wooden mallets, the pavement is sprinkled with wet sand and then alternately hammered and wetted with water to compact the surface and ensure that the cobbles are tightly packed.

Modern installation: the cobbles are set in a base of sand and binder or cement mortar. In the case of a dry cobblestone pavement, the last phase of installation requires the sealing of the interstices with a lime and cement solution (or cement alone); this must be performed with great care to prevent the paved surface from having poor wear resistance.

The cobbles are usually set vertically for greater resistance to the wear caused by vehicle traffic; they may also be laid flat (oblong cobbles) or edge set but this solution should be used only in pedestrian areas.

The cobbles are laid lengthwise according to the gradient of the paved surface, to ensure the channeling of rainwater in the drainage system (gutters, drains). In the case of cobblestone areas with guide strips or other worked stone elements, these should be set in place first and, since they will be subjected to vehicle traffic, they need to be joined and fixed in an appropriate manner.

Laying Cube Paving

The base course of a cube pavement may consist either of sand or sand mixed with cement.

Sand course: this is laid on the sub-base, to a final thickness of 4/6 cm. Consequently, the sub-base must be laid at a level which makes allowance both for the sand course and cube thickness (see table on page 214).

The cubes are set on the sand bed in accordance with the planned design, always starting from the lower level of the area to be paved.

Sand and cement course: The sand (1 cu m) is mixed with cement (2 q) and the mixture is laid evenly on the sub-base. The cubes are then set in place.

To ensure the best resistance of this type of pavement, the joints between the cubes must be as narrow as possible.

When the gradient of the road changes or when the paved area crosses other areas, the arches must connected so as to ensure the greatest overall resistance of the pavement.

Tamping/Vibrating

Once the cubes have been laid on the base course, they are tamped, i.e., the paved area is accurately leveled and compacted by means of pressure. In ancient times, this step was performed by means of large tampers (iron-headed clubs weighing about 25 kg), which are still useful for maintenance of small sections of pavement. Nowadays, this compacting operation is called vibrating, and is performed using motor-operated vibrating disks, appropriate to the size of the cubes. This makes it possible to pick out slight imperfections in laying (small depressions of the cubes or joints, damaged cubes which split and fracture when the disk runs over them). Before vibrating, the pavement is sprinkled with sand to fill up the spaces between the cubes and must be sprayed with water throughout all the vibrating cycles.

Sealing

This is an essential process for water-proofing the joints. Good sealing avoids the infiltration of water and the consequent disappearance of sand, it avoids the wearing of the sharp edges of the cubes and preserves the pavement from sapping. Sealing can be performed using either sand, sand and cement or cement grout. **Sand sealing** makes it simple to recover the elements in their entirety in the event of subsequent excavation or restoration works, it makes the paved area more resistant to wear but it does not prevent the growth of weeds in the points not subject to pedestrian wear.
Sealing with cement grout employs a liquid compound (fine grained sand, water and cement) which is spread over the pavement and left to soak in for about two hours. The excess cement grout is then carefully removed using sawdust and brushes; care must be taken to ensure that the compound residue does not obstruct the drainage systems.
Where sand has been used as a base course, sealing will be superficial only, that is the cement grout will not seal with the base course.

Laying Flagstone and Tile Paving

The installation of flags is less complicated than that of cubes. The base course consists of cement mortar (masonry sand, water, cement and lime) of thickness min 2/max 6 cm which added to the flagstone thickness will determine the height of the sub-base, which in turn will vary according to the height established for the finished pavement. Before installation, it is advisable to douse the flagstones in clean water to remove all traces of dust and in general terms favor adhesion of the single elements to the base course. Vibrating and sealing with cement grout are operations similar to those described for cube pavements. The gradient for rainwater drainage, about1-2%, should be indicated by the operator by means of ropes. The joints between the elements, above all when the paving units have split edges, must be not less than 1 cm so that the mortar can make the irregular edges uniform. On the other hand, a 3-5 mm joint will suffice for sawn slabs.
During installation, the natural hues of both flagstones and tiles may be enhanced by the installer, who can group elements of similar color, and/or contrast different hues, so as to produce chromatic patterns of great aesthetic effect.

*Laying Crazy Paving (***Opus Incertum***)*

This type of paving follows the same method of installation as the regular flagged pavement, with thickness of the cement mortar base course of 2-6 cm.
Installation must be performed with great care in the case of surfaces destined for vehicle traffic, with painstaking filling and leveling of the joints (joints ± 2.5 cm). The joints between the elements should not exceed 2/3 cm and great care must be taken to avoid leaving empty spaces between the slab and the mortar (moderate tamping with a rubber mallet).
In the case of landscaping pavements (in green areas), grass joints can be used over a thin course of sand: from the rolled ground (even using a simple garden roller) a layer of grass turf

must be removed equal in thickness to the slab plus the sand (2.5 – 3 cm) and the level of the stone surface with respect to ground level (1.5 – 2 cm). This is necessary to avoid damage to the blades of the grass mower. The larger stones are set at the sides of the pathways; after setting the slabs in the sand by means of tamping, the joints are filled by sprinkling with a mixture of sand and sieved earth and the turf is set in the joints; as it grows, its roots will further stabilize the pavement.

LAY PATTERNS FOR CUBES

For laying of the elements on their base course, iron shapers are used along the external edge of which the greater arch is placed. The patterns most commonly found for cube pavements are: Segmental arches, Herringbone, Florentine pattern and Stretcher bond (parallel lines).

Segmental arches: this is the design most commonly used for trafficked areas because the arch is the structural element which offers the best resistance to the typical horizontal wear induced by heavy loads. Each arch is opposed to the arch by its side, with which however it shares the structural base element. The joints diverge towards the top of the arch. The fundamental rule for the laying of segmental arches is that two half arches must always be set at the sides of the road. In roads with a barrel-shaped transverse profile (frequently found in historical centers) the number of the arches must always be equal so that there is a whole arch at the centre of the street. If the width of the street does not allow for an equal number of arches, the space available must be re-measured to permit the laying on each side of the street of one or more (even three) rows of cubes of the same size or larger than those forming the arches. These edging rows can even act as true drainage gutters. Above all, arch patterns should head up the natural gradient for obvious reasons of mechanical resistance, and installation must start at the lowest level. The width of the arch is planned according to the sizes of the cubes used.

Herringbone: the smaller cubes are not set in a straight line but in a herringbone pattern (more resistant to stress and thus to disconnection) since the arches are truncated at a certain height to allow the insertion of other truncated arches.

Florentine pattern: this is a particularly effective pattern suitable for use in large paved areas. The cubes are laid so as to obtain a series of half-circles in the middle of which are set the successive non-aligned half-circles.

Stretcher bond cubes: the cubes are set side by side in parallel rows. The rows should not be too long since the difference in size of the cubes would make it difficult for the layer to maintain a perfectly straight line and this might spoil the aesthetic effect by creating irregular joints. Before installation, the cubes should be size-graded to obtain a surface which is as far as possible uniform. With respect to the architectural element, the cubes may be placed parallel, orthogonal, herringbone, or at various angles. For particular types of pavement, cubes may be specially produced with reduced dimensional tolerances in the same size range.

Key words

Intersections between arches	sides: smaller cubes.
Centre of the arches	head: larger cubes.
Paving section	section of the surface to be paved, of varying width depending on the size of paving units and the total size of the area. Each section is traced by means of ropes that mark the planned gradients and levels of the paving.
Edging row	a straight row of cubes laid as edging to the carriageway, along the ropes that mark the external perimeter of the road paving.
Binders	end-of-row cubes.

Cobblestone

Two laying patterns using round and oblong cobblestones.

Foundation soil and Sub-base for External Paving

Foundation Soil

Careful evaluation of the foundation soil is essential to prevent subsidence or other structural alterations of the pavement. **For this reason, especially when dealing with extensive paving projects, the consultancy of a geologist should be sought**. Any soil is constituted by a natural agglomerate of mineral and organic particles, based on whose characteristics (shape, structure, size, presence or lack of moisture) the soil can be identified and classified as to grain size. Loose soils are those with loose particles, without binder (without water) whereas cohesive soils are those which have hydrated particles and which, by reason of the capillary tension exerted by the water, are resistant to shear.

Important parameters for the evaluation of the mechanical behavior of a soil

- Internal friction (this increases with the increase in particle size).
- Compressibility.
- Freeze reaction (reaction to the increase in mass following freezing of pore water).
- Cohesion (shear strength).
- Elasticity (the ability of soil to reexpand after being compressed).

Grain size classification parameters

Material	*Grain size (mm)*
Stones	*> 60*
Gravel	*2 - 60*
Sand	*0.06 - 2*
Silt	*0.002 - 0.06*
Clays	*< 0.002*

Sub-base

Sub-bases in use at the present time are in gravel (stone size decreasing towards the laying surface), concrete, which may be reinforced with a metal grid, or concrete blocks, also reinforced, (for particularly heavy loads). In the latter case and always when dealing with extensive paved areas, in view of the well-known thermal dilation which affects concrete, it is essential to plan for expansion/contraction joints, which need to appear also in the paved surface itself to prevent reduced resistance to stress.

The sub-base must have a depth suitable to the pavement type and the gradients (~1-2 %) of the finished work. An excessively thick or thin sub-base may indeed compromise the uniform distribution of the bed and determine diminished load resistance over the whole paved surface. In these cases, it is advisable to level the sub-base, as described in general terms hereunder.

- **Sub-base for cement mortar bed:** use mortar also to level the sub-base.
- **Sub-base for sand bed:** to level humps, tamp the sand, taking care that the thickness of the sub-base is never less than 4 cm; to fill dips or hollows, add sand but do not exceed, after tamping, sub-the base thickness required for the type of pavement (e.g. 5-6 cm in 4/6 and 6/8 cube paved areas).

In the case of substantial unevenness, action must be taken to remodel the sub-base itself.

- Evaluation of foundation soil in order to determine its sub-base support characteristics: see Tab.B, page 212.

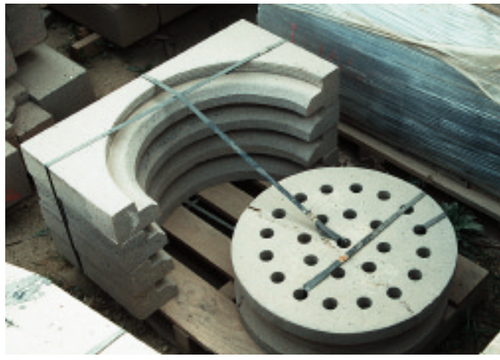
Stormwater Drainage Systems

Any pavement increases the surface run-off coefficient (whose ideal value is 0) and reduces its capacity to absorb stormwater (rain, hail, snow). During project planning, it is necessary to calculate, on the basis of the highest rainfall values for the area and rain intensity per hour, the maximum amount of water to be channeled by the drainage system and the required properties of metal or stone drains (openings cut into the curbstones, linear and curved grills etc.) which are a necessary accessory to all external pavements. On the surface of the area to be paved, provision must be made for a system of gradients which draws the water to a series of pre-established points, avoiding pooling or puddles. For stone cube and flagged areas, the minimum gradient to guarantee this function is 1.5 - 2% and the maximum 10% (gradient required for asphalt trafficked areas = min.0.5 %-max 8%).
Sardinian Granite and Basalt may be used to produce a series of drains of thickness and design to order.

Runoff and Absorption Coefficients

Type of surface	Runoff coefficient φ (values)
Roofs	0.90-095
Asphalted surface	0.85-0.95
Stone paving	0.80-0.85
Stone paving on sand bed	0.60-0.70
Cobblestone on sand bed	0.40-0.60
Non-compressed gravel	0.15-0.30
High density urban flagged areas	0.70-0.90
Medium density flagged areas with virtually continuous cover	0.50-0.70
Urban areas with public & private gardens	0.20-0.50
Barren land	0.10-0.30
Green and wooded areas	0.00-0.25

(Adapted from Frübling's scale)



Uneven surfaces required for storm water drainage systems are the parts of paving most exposed to traffic stress. Traffic load, speed and frequency and water runoff speed are among the main important parameters to be assessed when selecting surface drainage systems and the stone materials to be used.

In this regard, reference standards for the designer (which define types, construction methods and listing of paving drainage systems based on load class) are:

DIN 19580 (surfaces by load class and linear drainage);
DIN 1213 and DIN 19599 (drainage systems and covers).

Classification of foundation soil with regards to its support of the sub-base

Soil	*Quality*
Rocky, gravely, compact sandy, dry clayey	*good*
Clayey - sandy, moist clayey	*poor*
Marshy, vegetable	*bad*
Sandy	*bad**

- Foundation soil: the layer of natural material (not imported fill material) supporting the sub-base, the base and the paving course.
- Sub-base: slightly or not compressible material placed in a layer between the foundation and the base.

* *May be acceptable if the sand is kept in place by containing structures on the edges of the paved area.*

Regional Law n. 30 of 7-6-1989
"Regulations Governing Quarrying Activity"

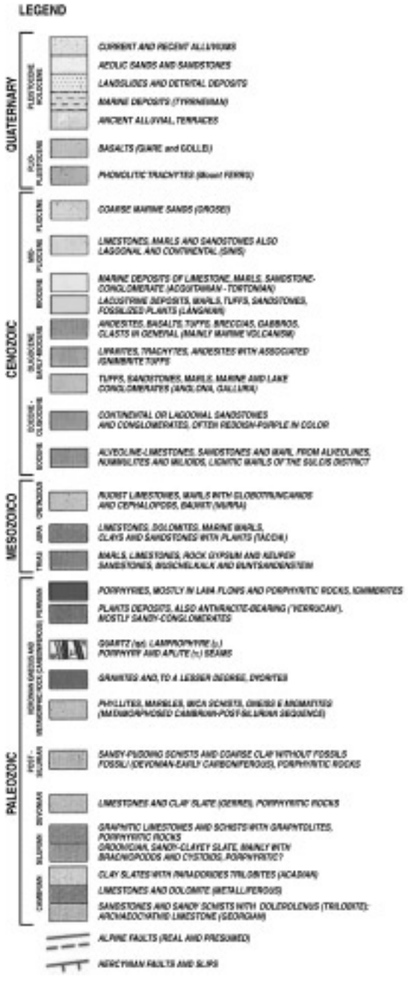
Regional Law n. 30 of 7-6 -1989 'Regulations Governing Quarrying Activity' and subsequent amendments establishes the rules for the issue of licenses for the exploitation of stone deposits and for the setting up of a Regional Registry of such deposits. These documents furthermore define the 'Regional Plan for Extraction Activities' (*Piano regionale delle attività estrattive" - P.R.A.E.*), based on the cartographic support of the 'Map of areas free of constraints and which may be utilized for quarrying activity' which in turn is based on the data produced by Progemisa S.p.a. within the framework of the SIPAC - *Sistema Informativo Pianificazione Attività di Cava* (Information System on the Planning of Quarrying Activity).
This Regional Plan, in identifying new areas open to quarrying, takes into account the following: current regulations protecting the regional heritage (environment, scenery, hydro-geological resources, archaeological sites, paleontological and paleo-ethnological sites, caves; protection of biotypes and vegetation and soil resources etc); the constraints and limitations set out in the Municipal Zoning Plans for those areas with specific assigned uses; constraints of any other type.

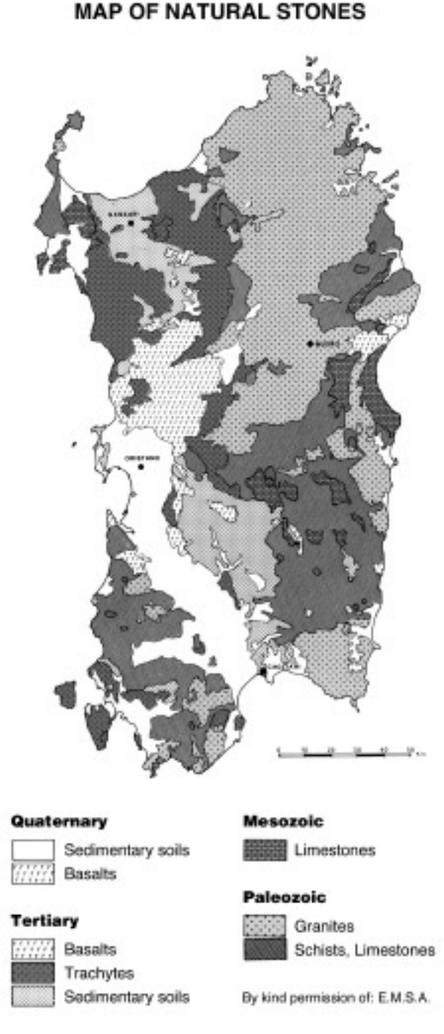
National regulations for the identification of areas in which quarrying activity is not permitted:
- R.D.L. n. 3267 of 30.12.1923,'Hydrogeological Constraints'
- L. n.1089 of 1.6.1939, 'Protection of artistic and historical assets'
- L. n. 1497 of 29.6.1939, 'Protection of natural beauties'
- L. n. 431 of 8.8.1985, (known as Galasso Law)
- D.A.R. n. 2997-3012 of 23.12.1985.

Regional Laws Subsequent to Law n. 30/1989:
- Reg. Law n.31 of 7.6.1989 'Regulations governing the management of Parks, Nature Reserves and natural monuments, as well as areas of particular naturalistic and environmental importance'
- Reg. Law n. 45 of 22.12.1989 'Regulations governing the use and protection of the territory'
- Decrees of the President of the Regional Council of 6.8.1993 and Executive Decree covering the 14 Scenic Plans and associated implementation regulations (S.o. B.U.R.A.S. n. 44 of 19.11.1993).

Location of Sardinia's Regional Nature Parks

Legends of the Maps on pages 2 and 3

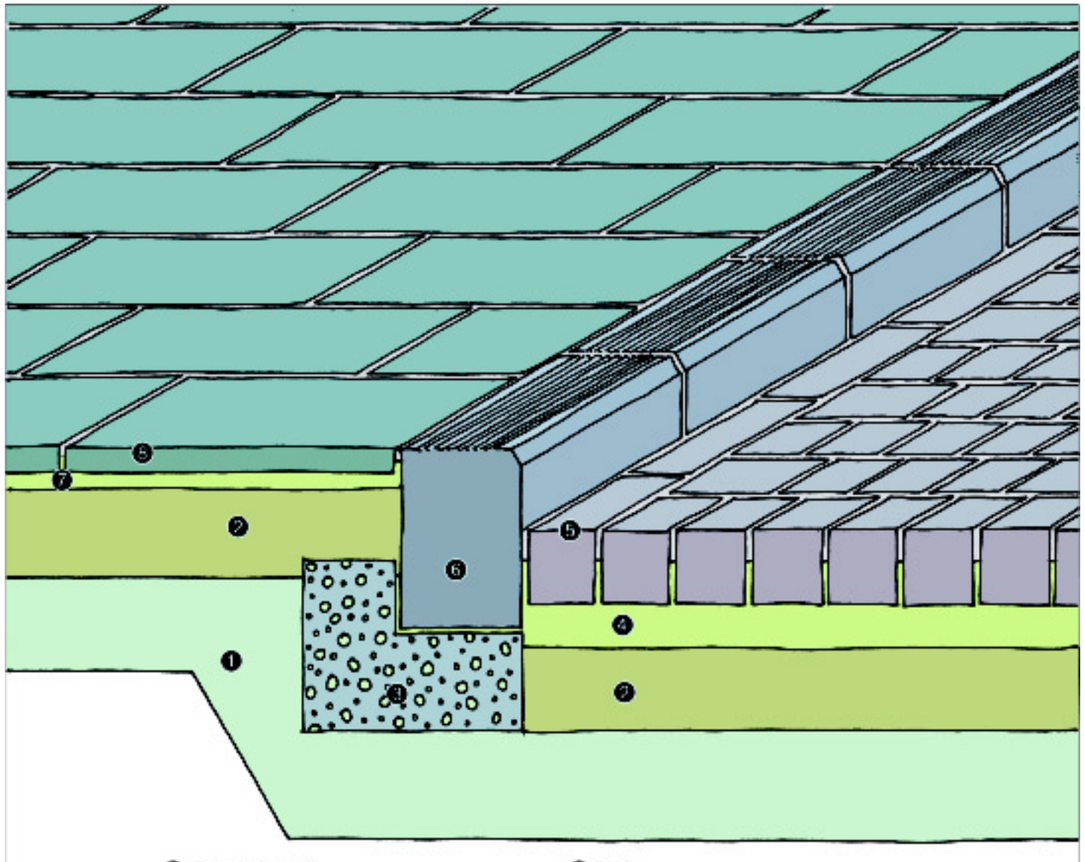




Legend of the Map on page 6

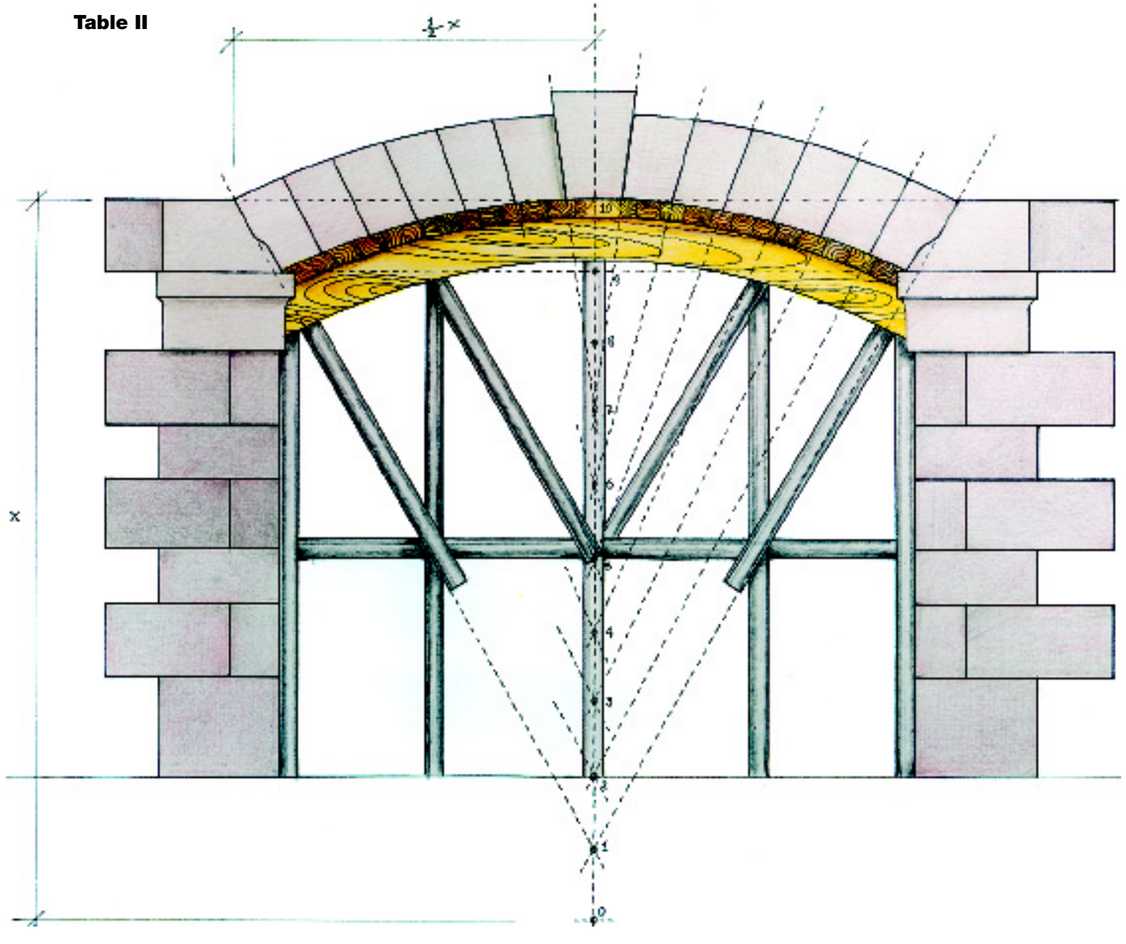
Table I

Cross-section of cube paving



1. Foundation soil
2. Sub-base +/- 15 cm (ballast or concrete-mortar course)
3. Concrete support
4. Base course: sand
   - 4 cm (4/6 cm cubes)
   - 5 cm (6/8 cm cubes)
   - 6 cm (8/10 and 10/12 cm cubes)
5. Ditch
6. Curb (Chamfered edge)
7. Cement mortar
8. Sidewalk (running length slabs)

Table II



Project drawing of the centering of a longitudinal arch

The drawing shows a coomb, a wooden frame that supports the arch structure until it has been completed.
In this case, the height of the arch is half the radius of the intrados (the interior surface of the arch).

The wedge-shaped ashlars are modular and placed at a distance equal to 1/10 of the arch. The wedge shape ensures that the ashlars exert contrasting forces one on the other.

0 = centre of the circle defined by the arch intrados.

Table III

Types of joints

Internal flooring slabs and tiles

1) Contact joint (sawn sides and sharp edge)

2) Contact joint (sawn sides and smoothed edge)

3) Plane joint (sawn sides and sharp edge)

4) Lowered edge joint (sawn sides and smoothed edge)

5) Lowered edge joint (sawn sides and sharp edge)

6) Wide lowered edge joint (split sides)

7) Wide joint with filler soil or grass (split sides)

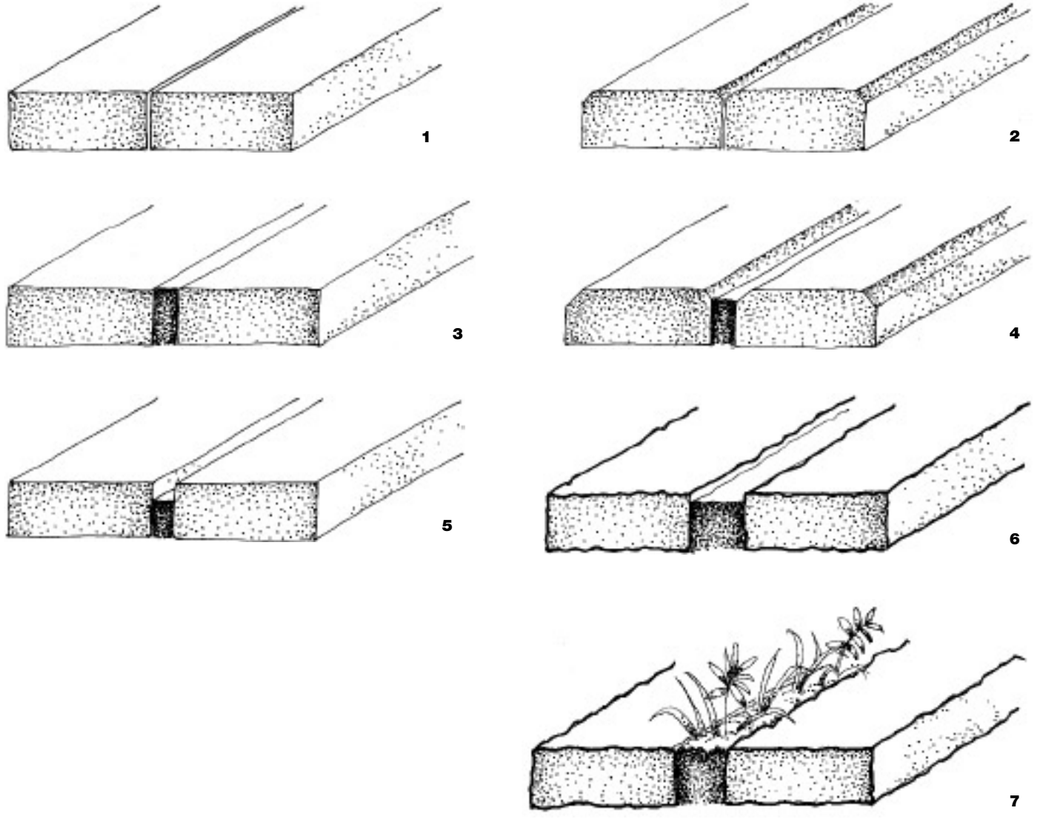


Table IV

Types of tread edges

1) Square edge

2) Square side with chamfered edges

3) Eased edge

4) Half bullnose edge

5) Bullnose edge

Other types of edges

A) Cove edge

B) Reverse ogee edge

C) Ogee edge

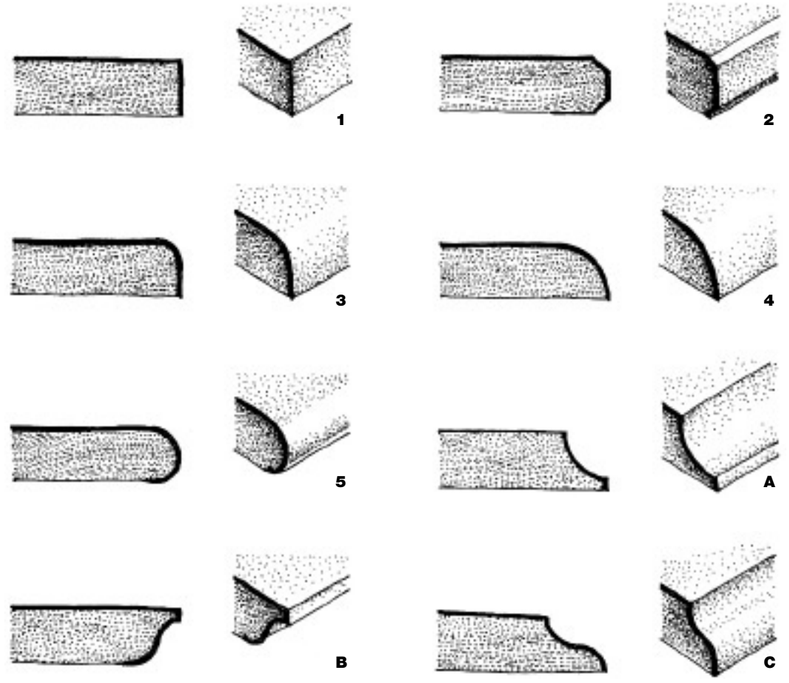


Table V

Concentric circle design

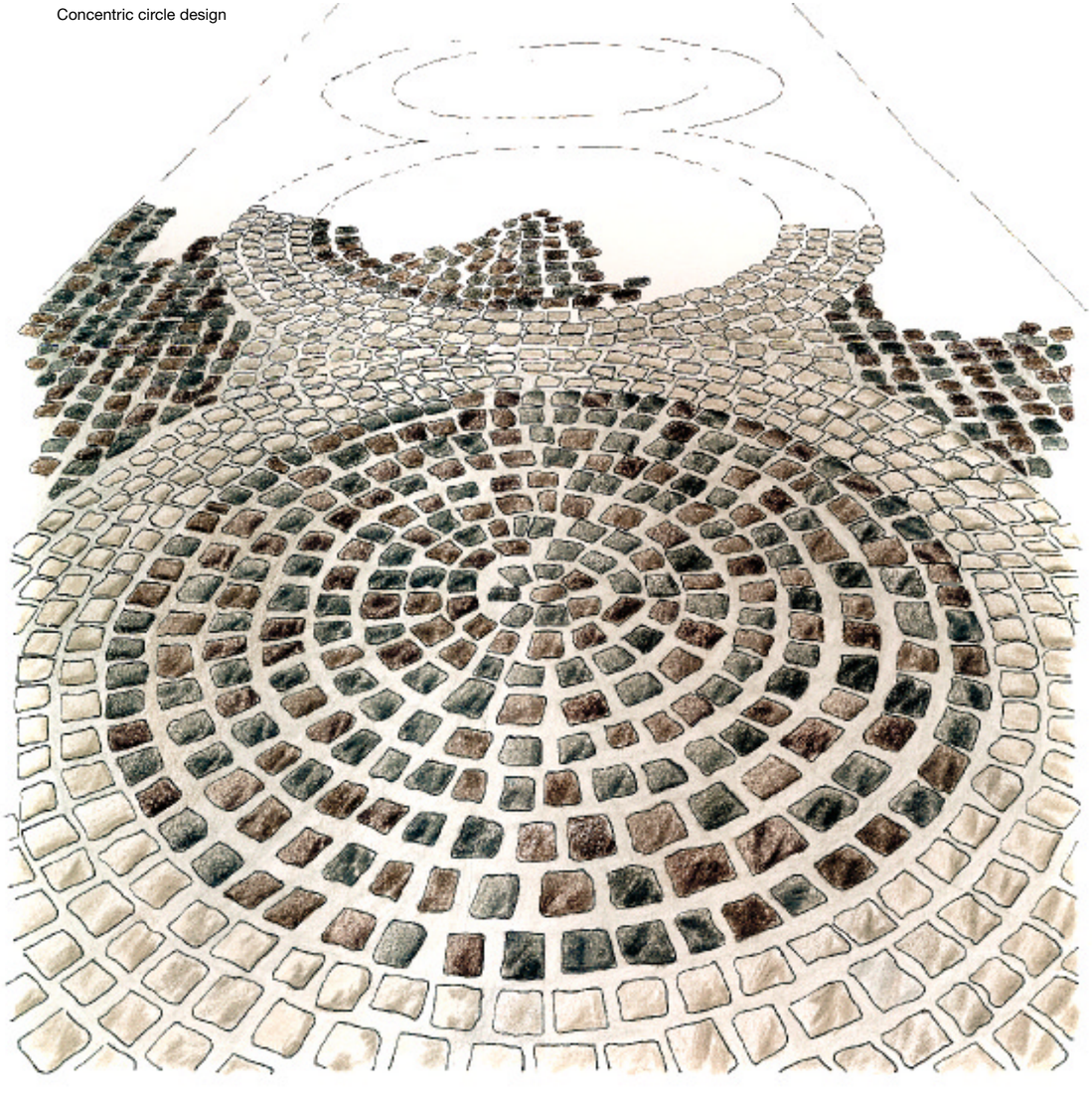
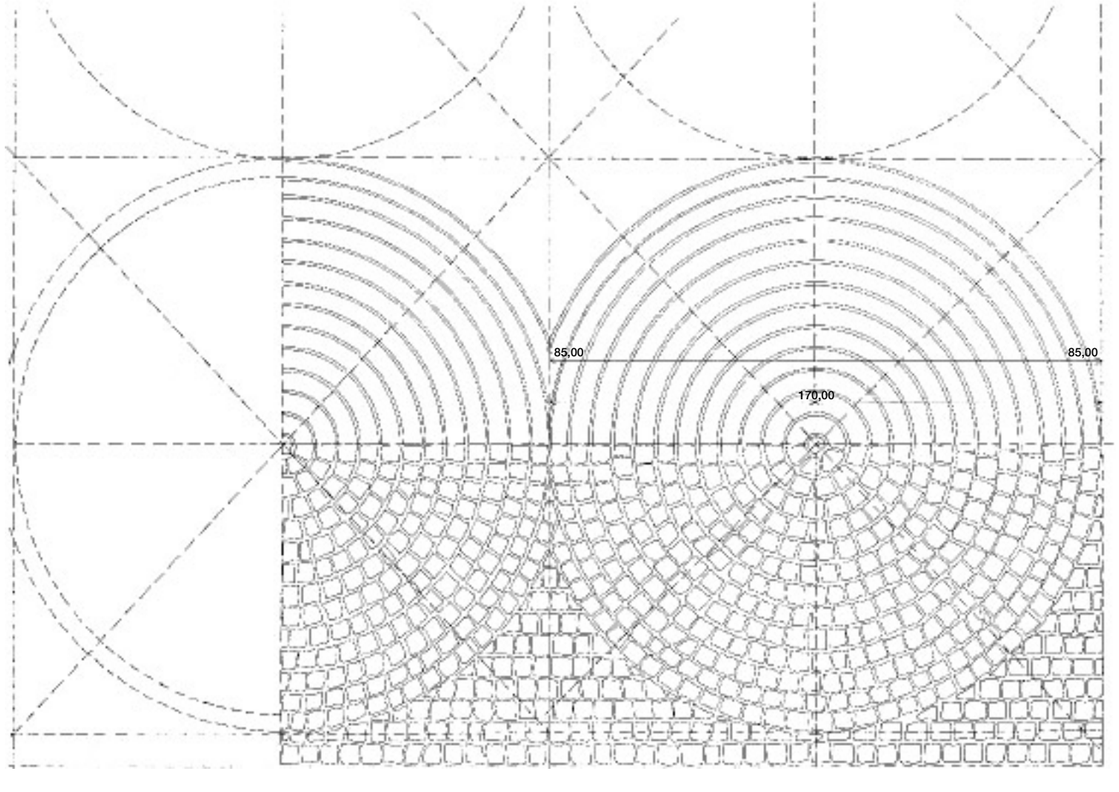


Table VI

Concentric circle design - geometric drawing



External Paving in Sardinian Basalt Andesite Cubes

Supply and installation of paving in ***Sardinian Basalt Andesite, in cubes with split sides, surface face and back with natural finish (quarry face), in 6/8 and 8/10 cm sizes,*** to be laid according to project drawings on a 6 cm-thick cement mortar base course, consisting of sand of the appropriate grain size dry-mixed with R 3.25 cement in the ratio 10 kg/sq m.

Supply price shall include the following work: supply and laying of the base course; establishment of the required gradient for rainwater drainage; vibrating; replacement as needed of any cubes broken or chipped during laying; sealing of the joints with cement grout and sand; subsequent surface cleaning with sawdust and/or water and any other operation required for a workmanlike execution.

• ***Preparation of sub-base not included***

Cost Euro/m²

External Paving in Sardinian Basalt Setts

Supply and installation of ***Sardinian Basalt paving, in running length setts, cm 6 in height and 3 cm in thickness, with tumbled (antique) surfaces and smoothed edges.*** The paving shall be installed, according to project drawings, on a 6 cm-thick cement mortar base course, in the ratio 250 kg type R 3.25 cement to 1 cu m of sand of the appropriate grain size.

Supply price shall include the following work: supply and laying of the base course with a surface cement coating – not less than 6 kg/sq m; establishment of the required gradient for rainwater drainage; vibrating; replacement as needed of any setts broken or chipped during laying; sealing of the joints with cement grout and sand; subsequent surface cleaning with sawdust; cutting, trimming and any other operation required for a workmanlike execution.

• ***Preparation of sub-base not included***

Cost Euro/m²

External Paving in Sardinian Basalt Slabs

Supply and installation of external paving in ***Sardinian Basalt Slabs, in cut-to-size slabs measuring 30x40 cm, thickness 6 cm, with rough sandblasted face, sawn back, sides cut to 90 degrees and smoothed edges.*** The slabs shall be installed, according to project drawings, on a 6 cm-thick cement mortar base course, in the ratio 250 kg type R 3.25 cement to 1 cu m of sand of the appropriate grain size.

Supply price shall include the following work: supply and laying of the base course with a surface cement coating – not less than 6 kg/sq m; establishment of the required gradient for rainwater drainage; vibrating; replacement as needed of any slabs broken or chipped during laying; sealing of the joints with cement grout and sand; subsequent surface cleaning with sawdust; cutting, trimming and any other operation required for a workmanlike execution.

• ***Preparation of sub-base not included***

Cost Euro/m²

External Paving in Irregular Sardinian Basalt Slabs (Opus incertum)

Supply and installation of ***Sardinian Basalt paving, in irregular slabs, medium sizes, thickness 6 cm, length of diagonal 15/25 cm, sawn face and back and split sides.*** The paving shall be installed, according to project drawings, on a 6 cm-thick cement mortar base course, in the ratio 250 kg type R 3.25 cement to 1 cu m of sand of the appropriate grain size.

Supply price shall include the following work: supply and laying of the base course with a surface cement coating – not less than 6 kg/sq m; establishment of the required gradient for rainwater drainage; vibrating; replacement as needed of any slabs broken or chipped during laying; sealing of the joints with cement grout and sand; subsequent surface cleaning with sawdust; cutting, trimming and any other operation required for a workmanlike execution.

• ***Preparation of sub-base not included***

Cost Euro/m²

Interior Wall Facing in Sardinian Basalt Slabs

Supply and installation of ***Sardinian Basalt interior wall facing, in cut units of different sizes, thickness 2 cm, honed face, sawn back, sides sawn to 90 degrees, and sharp edges.***

The units shall be installed, according to project drawings, with cement mortar, in the ratio 250 kg type R 3.25 cement to 1 cu m of sand of the appropriate grain size.

Supply price shall include the following work: cost of supply and laying of the mortar; sealing of the joints; repairing of plaster as needed; finishing round window and door frames; replacement of any slabs broken or chipped during installation; subsequent surface cleaning, cutting, trimming and any other operation required for a workmanlike execution.

No. 15x25 cm tiles; thickness 2 cm
No. 20x30 cm tiles; thickness 2 cm
No. 25x30 cm tiles; thickness 2 cm

Extra cost for supply of additional sawn square tiles

Extra charge for supply and installation of ***Sardinian Basalt internal wall facing*** (various sizes) to include additional units such as sawn square tiles ***Sardinian Basalt measuring 12x12 cm, thickness 2 cm, honed face, sawn back and sharp edges.***

No. 12x12 cm tiles, thickness 2 cm

Cost Euro/m²

GLOSSARY

Apparent density (UNI 9724/2)
This is the value which expresses the weight of the rock as it is present in nature; it is indicated in kg/m3 or in g/cm3 and is derived from the ratio between the weight (in kg or g) and the apparent volume (volume marked by the external surface) of a cubic sample with 7.1 cm side. The specific weight of the rock is on the other hand provided by the ratio between the weight of the pulverized sample (that is without vacuums) and the weight of a similar volume of distilled water. The comparison of the values of the volume weight and the specific weight gives the degree of compactness of the rock, an important indication when assessing resistance and durability. In compact rocks (granite, basalt, porphyry and compact limestone) specific weight and volume weight tend to coincide, whereas in porous rocks (pumice, tuff, soft limestone and sandstone) the difference can be quite significant.

Batholiths
(From the Greek *bathis*, deep, and *lithos*, stone): huge granite formations whose base reaches deep into the earth, at non measurable depths. Mont Blanc is an example of a batholith.

Cleavage plane of a rock
Divided into: 'horizontally striking direction or *pioda'* (the plane which may be more easily split); 'East-West striking direction or *trincante'* (less easy to split); 'counter direction or *mozzatura'* (the least easy to split).

Cut slab
Slab cut into the required sizes (commercially, various types of tiles).

Durability
Resistance of rocks to weathering agents (rain, sun, ice, wind), mechanical agents (loads, surface abrasion) and to various polluting agents, both chemical (sulphur dioxide and carbon dioxide) and biological (molds, lichens). Durability can be affected also by various types of inclusions or structural defects of a mechanical nature (e.g. cleavage planes not visible to the naked eye). Climate and site exposure are also important: a dry, regular climate with reduced temperature excursions favors durability. Also, smooth surfaces are more resistant than textured ones: uniform polishing prevents pooling of water and the growth of microflora, which may affect surfaces with North exposure.

Fixed length slab
Stone unit with fixed measures, purposely made for a given project.

Head
The side surface of a slab, whose dimensions are length and width. Only with respect to curbs is the upper layer in view called head.

Length, width, thickness
In a rectangular element or element of similar shape, the largest dimension is called length; the intermediate is called width while the smallest is known as thickness.

Mill block
Squared block of the appropriate size for gangsawing.

Non-slip paving
Paving installed using materials whose attrition coefficient, measured in accordance with the method adopted by the British Ceramic Research Association Ltd. (CERAM) rep. CEC.6/81, is higher than the following values: 0.40 per leather slip element on dry pavement; 0.40 per standard hard rubber slip element on wet pavement.

Quarry block
A rough bock, still to be squared.

Running length
A length not less than 1.5 times the width.

Squared block
A block cut into a regular geometric form, usually rectangular.

Side
The lateral surface of a slab, whose measurements are the length and thickness of the slab.

Slab
Cutting stock, of thickness ranging from 20 to 80 mm and considerable length and width. Slabs less than 20 mm thick are called thin, those exceeding 80 mm are called thick slabs (or, incorrectly, thicknesses).

Thin section
An optical method used to determine the nature of minerals present in a rock. It is based on observation, through a microscope which may use either polarized or natural light, of rock flakes of 0.01-0.05 mm thickness.

Tolerance
Dimensional wastage with respect to the dimensions normally defined for a product.

UNI regulations regarding natural stone
The UNI is the Italian agency, legally recognized at Community level, which issues technical regulations covering all industrial sectors (with the exception of electrical regulations, which are the responsibility of the CEI) and promotes the application of such regulations.

UNI 8458
Terminology and classification of stone products used in the building trade.

UNI 9379
Terminology and classification of stone pavements.

UNI 9724/1
Petrographic description of natural stone materials.

UNI 9724/2
Determination of apparent volume mass and imbibition coefficient.

UNI 9724/3
Production of thin, polished sections.

UNI 9724/4
Determination of resistance to simple compression.

UNI 9724/5
Determination of resistance to flexural compression.

UNI 9724/6
Knoop micro-hardness test.

UNI 9724/8
Determination of normal elasticity module.

UNI 9725
Acceptance criteria.

UNI 9726
Worked and rough stone products. Criteria for technical information.

UNI Information Office:
Via Campania 31 - 00187 Roma - Tel. 06/47.44.032;
Piazza Diaz 2 - 20123 Milano - Tel. 02/72.14.71.

Workability
Stone workability, or its aptitude to be cut and shaped, depends on the stone's structural properties and hardness. Workability is mainly affected by: splitting potential, an important property for split face paving and wall facing units; sawing potential, i.e. the ease of cutting with toothed saws (for soft rocks such as tuff, pyroclasts and soft limestones), disk saws and silica sand (for semi-hard rocks such as other soft limestones, sandstones etc.), smooth saws and quartz sand (for hard rocks such as compact limestones etc.), diamond saws (for very hard rocks such as granite, basalt etc.). Sawability is a critical factor when assessing a given stone's fabrication cost, from block quarrying to slab and other cutting stock production; finally there is carving potential, i.e. the pliancy to manual (chisels, scoring tools, picks, etc) or pneumatic tools.

INDEX

The page numbers are listed by decreasing amount of information (text, captions and pictures) on each item listed. Where no page numbers are given, the item can be found in the website www.lapideidisardi.it.

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ANTICA CAVA
S.S. Martiri 21 - 09083 Fordongianus (OR)
Tel/Fax 0783/60.183
Quarrying of Red Trachyte and working of Trachyte.

ARTE PIETRA
Loc. Mura Crabas 09070 Bauladu (OR)
Tel/Fax 0783/67.503
Quarrying and working of Basalt.

C.P. BASALTI s.r.l.
Via Sassari, 5 - 08016 Borore (NU)
Tel. 0785/86.045 - Fax 0785/86.305
Zona Industriale Tossilo - Macomer (NU)
Tel. 0785/86.814
Working of Basalt - Granites - Marbles - Trachytes.

DEIANA PAOLINO GRANITI
Via Ghiberti 18 - 07026 Olbia (SS)
Tel/Fax 0789/50.431
Quarrying and working of Sardinian Granites.

FIORE SALVATORE GRANITI
Via D. Chiesa - 07020 Buddusò (SS)
Tel. 079/71.52.34 - Fax 079/71.45.59
Quarrying and working of Sardinian Granites.

G.M.C.
Loc. Su Padru - 09076 Sedilo (OR)
Tel. 0785/56.80.05 - Fax 0785/56.81.35
Quarrying of Basalt - Working of Basalt - Marbles - Trachytes

GRANITI e MARMI di Sardegna S.c.a.r.l.
Via Galassi 2 - 09100 Cagliari
Tel. 070/27.29.70 - Fax 070/27.18.96
This Consortium consists of 98 Sardinian Enterprises engaged in this sector. Quarrying and working of Sardinian Granites and Marbles.

MARMI e GRANITI di Orosei S.c.a.rl.
Via Matteotti 55 - 08028 Orosei (NU)
Tel. 0784/99.70.55 - Fax 0784/99.83.62
This Consortium consists of 7 Enterprises engaged in this sector. Quarrying and working of Orosei Marbles and Granites.

MISTRAL GRANITI s.r.l.
S.S. 127 Km. 3.300 - 07026 Olbia (SS)
Tel. 0789/31.031 - Fax 0789/31.154
Quarrying and working of Sardinian Granites.

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Tel/Fax 0789/50.71.07
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PERDAS S.a.s.
Zona Artigianale - 09070 Paulilatino (OR)
Tel. 0785/55.800 - Fax 0785/56.61.70
Working of Basalt - Trachytes - Natural stones.

PILOT PROJECT
‘NATURAL STONE FROM SARDINIA’

P.O.P. SARDEGNA
misura 2.2.3.1

Managing Director:
Dr. Francesco Marcheschi
(Consorzio 21)

Co-ordination:
Dr. (Geol). Mara Mangia, Dr. Giuseppe Serra
(Consorzio 21)

TECHNICAL HANDBOOK

Project: Claudia Di Prospero and Pietro Deriu

Editorial Co-ordination and texts: Claudia Di Prospero

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The maps on pages 2 and 6 were taken from the publication Le pietre ornamentali di Sardegna *(Industry Dept. of the Autonomous Region of Sardinia,1999) which was produced, using data supplied by the R.A.S. Quarry Office, by the Cartographic Service, (Giancarlo Cabras, Antonello Lavena) of Progemisa S.p.a.*

The map of stone types on p. 3 was taken from the publication Graniti e Marmi di Sardegna*, E.M.S.A., 1987*

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Project: Luigi Spanu, Antonello Pilu, Massimo Migoni

Texts: C.D.P.

Hypertext: C.D.P. e Pietro Deriu

Processing: Gabriele Bianco, Valentina Ferrari, Barbara Sanna

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Project: Marco Dore, Massimiliano Pani

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Project: Marco Dore, Massimiliano Pani

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Eng. Gianpaolo Siotto

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Prof. Barbara De Nicolo

Arch. Sebastiano Gaias

Eng. Stefano Santoni

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